

Rehabilitation and Conversion of Coal-based Power Plants to Cogeneration Plants for Increased Efficiency

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ABSTRACT

The analyses of electric utility system operations and in resource planning are becoming more and more complicated since deregulation came to the power industries. The risk aversion strategy is leading generation planners toward minimum risk capacity planning decision and asset optimization.

Some of the most attractive alternatives, which result in scaled down capacity increments, include:

- Rehabilitation/upgrading
- Cogeneration or combined heat and power (CHP) generation

Power plant rehabilitation is a high ranged concept essentially aimed at continued operations of the generating unit at, or near rated capacities for an extended life of the plant. In many cases, conservatively designed older units with components that were specified with margin can be upgraded to yield additional capacity. The capacity increases are usually rather small and would not by themselves compensate for growth in demand.

In essence, the need to rehabilitate may arise due to reasons such as low availability factor, low efficiency, increasing operating and maintenance costs, loss of reliability, drop in safety of plant and personnel, poor maintainability or environmental requirements.

The term rehabilitation is therefore normally used in the context to cover the range of activities including repairing components, replacing equipment, modifying systems, adding new systems and equipment and perhaps restoration to rated capacities. This exercise on an already complex power generation process will naturally require the application of various technologies in order to ensure a safe and efficient installation of electricity supply and to adapt thermal power plants to the new conditions of the energy market.

This article covers general consideration, approach and methodology adopted by the Public Electric Power Company of Bosnia and Herzegovina for the implementation of the project - Rehabilitation and Conversion of Unit 4 (200 MW) in Thermal Power Plant (TPP) "Tuzla" to cogeneration unit, from the initial engineering studies through scoping of works, project viability analysis, anticipated targets and benefits, problems encountered and finally the achievements of the project.

INTRODUCTION

1. Thermal Power Plant (TPP) Tuzla is part of the current Elektroprivreda Bosnia and Herzegovina (EP BiH). EP BiH is public sector enterprise owned by the Federation of Bosnia and Herzegovina. Established in 1993, EP BiH has installed capacity of about 1,830 MW, of which 474 MW is hydropower and the balance is thermal power coal based. The customer base is slightly higher than 620,000-metered customers. Table 1 shows the available capacity of the various TPP and hydro-power plants (HPP) units on the EP BiH system for the year 2000. Figure 1 shows map of electricity generation sites in Bosnia and Herzegovina.
2. TPP "Tuzla" had a few phases in its operation and development. These phases could be apportioned as follows:
 - Phase 1(from 1965 to 1992) prior to the war: This is phase of intensive construction (within this period a total of 775 MW were built), preparation for rehabilitation of old units and construction of new units TPP Tuzla B (500 MW) and TPP Tuzla VI (360 MW).

Table 1. EP BiH Power Plant Capacities

	INSTALLED DESIGN CAPACITY GROSS(MW)	INSTALLED DESIGN CAPACITY NET(MW)	CURRENT AVAILABLE CAPACITY NET(MW)
THERMAL-ELECTRIC			
TPP Tuzla			
Unit 1	32	29	25
Unit 2	32	29	25
Unit 3	100	91	91
Unit 4	200	183	0
Unit 5	200	183	170
Unit 6	215	197	180
Sub-Total Tuzla	779	712	491
TPP Kakanj			
Unit 1	32	29	0*
Unit 2	32	29	23**
Unit 3	32	29	0*
Unit 4	32	29	25**
Unit 5	110	100	82
Unit 6	110	100	90
Unit 7	230	208	190***
Sub-Total Kakanj	578	524	410
TOTAL THERMAL	1357	1236	901
HYDROELECTRIC			
Jablanica		150	150
Grabovica		114	114
Salakovac		210	210
TOTAL HYDRO		474	474
TOTAL EPBiH		1710	1375

*Not available for future operation

**Reserve shut down

***Restricted power to 190 MW because of problems with frequent boiler tube cracking

- Phase 2 (from 1992 to 1995) the years of the war: The oldest units (2 x 32 MW and 1x 100 MW) were in operation. The units 3 x 200 MW were partially preserved to the extent possible. The operating units were subject to drastic frequency and loads change variations and were not adequately maintained.
 - Phase 3 (from 1995 to 1999): This was the period of the urgent after war renovation. Unit 3 (100 MW) was rehabilitated and Units 5 and 6 (2 x 200 MW) were restarted. The scope of repair for these units was limited to urgent needs sufficient to restart the units. TPP Tuzla Unit 4 was the last thermal unit to return to service.
 - Phase 4 (since 1999): This is period of intensive restructuring and deregulation of power sector (privatization, unbundling, regulatory condition, etc) in Bosnia and Herzegovina. The primary objectives of EP BiH and TPP Tuzla have been focused on reducing their costs, making their production more efficient and flexible, and evaluating risk and other economic factors.
3. The effect of uncertain load growth, coupled with deteriorating performances of the existing units in EP BiH system had led to management's decision to embark on this project. Set against the primary objectives of maximizing the operational efficiency and improving the financial viability and future competitiveness of EP BiH thermal plants, EP BiH undertook implementation of this project with the parallel objective of facilitating the back up and increasing the heating steam provided by TPP Tuzla.
 4. Focus had been put on rehabilitation of Unit 4 (200 MW) in TPP Tuzla, the only thermoelectric unit in the EP BiH system that had not yet been restarted since the war ended in 1995. It had been identified that rehabilitation/ restoring of this conservatively designed old unit, with components that were specified with margin, was an opportunity to significantly improve the capacity and efficiency of TPP Tuzla. In addition, because much of the work necessary to enable extraction of heating steam from Unit 4 had been accomplished before the war; this project should be completed to allow an economical and environmentally beneficial way to back –up and increase the heating steam provided by TPP Tuzla.

5. For a rehabilitation program, there are usually a number of general considerations which could form a basis for the planning criteria. The salient aspects could well be: the condition assessment of current plant equipment and systems including conducting the remnant life investigation even perhaps to extend the life of the unit; technical end economic evaluation of alternatives for refurbishing or re-powering including an introduction of an alternative fuel for economic or environmental reasons; assessment of environmental impact; and assessment of the market and demand for electricity and heat. Ultimately, the viability of rehabilitation will be determined by market factors, economic evaluation and risk assessment, rather than by purely technical consideration.

EP BIH-EXPERIENCE

Feasibility Study Objectives/Approach

A study was performed for the rehabilitation or re-powering of the TPP "Tuzla" Unit 4 (200 MW) and the TPP "Kakanj" Unit 7 (230 MW). The objective of this study was to identify a course of action that will enable the EP BiH system to satisfy present and future electricity demands with greater reliability and economy while also significantly reducing the environmental impact of their thermal generating units. The principal units under evaluation in this study were Tuzla Unit 4 and Kakanj Unit 7. However, it was not possible to completely isolate these units because:

- There are many common systems that serve all units at each plant;
- The approach to repowering or rehabilitation should consider the status and plans for the remaining units, and
- The dispatch of Tuzla Unit 4 and Kakanj Unit 7 depend on the overall condition of the remaining units. Therefore, during analysis of alternatives, all units are included in the investigations.

Data Gathering

A project team made up of local engineers and specialists from Parsons Energy and Chemical Group was formed and commenced work in August 1988, with a data collection exercise covering all units in TPP "Tuzla" and "Kakanj," with focus on Unit 4 in TPP Tuzla and Unit 7 in TPP Kakanj. The objectives included meeting with the station

personnel, verifying previously identified defects and shortcomings, assessing new requests, reviewing plant drawings, overhaul reports and documentation, and examination of operational and maintenance records. System electrical and heat demand and dispatch, availability of fuel and environmental requests are considered in parallel. The findings were then collated, evaluated and formulated into a basis for future development of the project.

The Assessment of Existing Plant Equipment

To evaluate the options for rehabilitation or re-powering, it was first necessary to establish the present condition and performance of the units. A plant assessment, similar to an EPRI level I assessment, was conducted for the two focus units and a less formal assessment was also conducted on the other thermal units. These assessments revealed that most of the units are suffering in reliability, efficiency, and environmental impact, due to the age of the plants, diminishing quality of coal, damage and inadequate preservation during the war years, and lack of maintenance funds for overhauls and improvements. In particular, TPP Tuzla Unit 4, which has not yet been restarted since the end of the war, was in very poor condition, with significant deficiencies in the areas of instrumentation and controls, boiler components and burner systems, steam piping, and flue gas dust removal.

As could be expected, creep damage was being detected in components exposed to high temperature and pressure.

The typical examples of the deficiencies and problems associated with major systems of the TPP Tuzla Unit 4 which will inhibit long term, reliable and efficient operation, are given as follows:

- Insufficient capacity of coal mills for full load operation with one mill out of service with lower quality coal. Fineness is inadequate at full load for complete carbon combustion
- Current coal combustion system can not produce required reduction in NO_x
- Oil burners not reliable and have poor combustion efficiency
- Structural beam (C*-C*) and supporting columns of the boiler are continually deforming due to hot gas leakage into space of beam
- Residual life of some parts of the boiler piping system are at the end of useful life
- Significant cracks were found on internal surfaces of feed water

regulation valves

- Significant crack progression has been found in some bend sections of live steam and hot reheat steam piping
- Over 13% of condenser tubes are currently plugged. This is expected to go up after restart. Result is higher condenser vacuum
- Inadequate performance of the electrostatic precipitator to meet long term environmental regulations
- Upgrade needed for the ash handling system
- 220-kV circuit breaker was not functional; could no longer repair or maintain; spare parts no longer available
- 6-kV circuit breaker and 0.4-kV switchgear can no longer repair due to lack of spare parts
- The turbine monitoring system is not providing reliable vibration information
- Existing primary control system (combustion controls, steam turbine, balance of plant) are outdated; no spare parts. Field instruments are obsolete, requiring all manual control of plant operating parameters and resulting in poor steam temperature control, combustion air control, high maintenance costs and inefficient tracking of plant operating data and faults.

Identifications of the Candidate Options for Evaluation

Based on the existing equipment configuration, discussions with the station personnel, experience and judgment, candidate options were developed for the evaluation of alternatives. These alternatives span the spectrum from rehabilitation to new construction including re-powering options and alternate fuel examination. Table 2 presents a list of options initially considered.

Prepare Preliminary Cost Estimates

Capital cost estimates, as well as O&M cost estimates, were prepared for the various options. For purposes of relative, economic comparison, the estimates are considered to be conceptual in detail, based on limited information from outside suppliers as well as from internal databases. When comparing options, the most important aspect of these estimates was the relative accuracy between options, and not the absolute accuracy. A greater degree of accuracy was pursued for the development of the project conceptual design and financial inputs.

Table 2. Initial Considered Options

Option identification	Description
1	Base Case: "Do nothing" except maintain existing operational units up to the point of normal retirement.
2a	Restart Investment TPP Tuzla Unit 4 only
2bT	Rehabilitation Investment, TPP Tuzla Unit 4 only
2bK	Rehabilitation Investment, TPP Kakanj Unit 7 only
2cT	Rehabilitation Investment, TPP Tuzla Units 3 through 6 only
2cK	Rehabilitation Investment, TPP Kakanj Units 5 through 7 only
2ALL	Rehabilitation Investment, TPP Tuzla Units 3 through 6 plus TPP Kakanj Units 5-7
3	Boiler Replacement, Pulverized Coal (PC): Replace existing boiler with new PC boiler, rehabilitate existing steam turbine.
4	Boiler Replacement, Fluidized Bed Combustor (FBC): Replace existing boiler with new FBC boiler, rehabilitate existing steam turbine.
5a	New PC Based Plant: All new boiler and steam turbine with supercritical steam parameters (225 MWe).
5b	New PC Based Plant: All new boiler and steam turbine with supercritical steam parameters (360 MWe).
6	New FBC Based Unit: All new boiler and steam turbine with modern steam parameters.
7	Repowering with Gas Turbine Combined Cycle Unit (GTCC): New GTCC installed in "best fit" configuration with rehabilitated existing steam turbine.
8	New GTCC based Unit: GTCC in optimum configuration with new steam turbine.

Generation Planning and Economic Analysis using ELFIN

In order to properly characterize the system, a computerized dispatch model, ELFIN, has been utilized in the economic analysis. This model, similar to WASP and other models, provides a simulated dispatch of units in a utility system in order to provide the most economical power generation, according to operational parameters and constraints placed on the units. The ELFIN model calculates net present value (NPV) of operating expenses for the period, as well as environmental emissions on a yearly and 20-30 year lifetime basis.

The ELFIN model is also used in sensitivity analysis to verify the validity of results with changes in various parameters such as capital costs, electricity demand projections including possible cross-border exports, fuel costs, replacement energy costs, and hydroelectric conditions.

The majority of inputs used in the generation planning input model were taken from existing feasibility studies, load forecast and generation planning documents. The available information included load shapes, annual energy consumption and peak demand projections, and plant specific information including capacity, average heat rate, forced and planned outage rates, primary fuel, and minimum capacities.

Results of Analysis

Considering the significant deficiencies revealed in the plant assessments of TPP Tuzla Unit 4 and TPP Kakanj Unit 7, it was evident that extensive rehabilitation, re-powering or replacement of these units must be considered if EP BiH is to reliably and efficiently meet present and future electrical load demands while reducing environmental impact of the thermal power generation. Of the options examined, it is observed that the full rehabilitation of Tuzla Units 3 through 6 and Kakanj Units 5 through 7 provides the lowest NPV of costs of all the options examined.

The favored option identifies rehabilitation of several thermal units within the EP BiH system, which satisfies the system analysis approach.

In an optimization study for SO₂ reduction, it is found that installing a wet scrubber on TPP Kakanj Unit 7 provides the most cost effective reduction in SO₂ among alternatives which included lime injection and dry scrubbers examined for multiple units. Further substantial, cost effective reduction of SO₂, which would enable compliance with World Bank and European Union standards, is identified as a wet scrubber to be installed for TPP Tuzla Unit 6. However, this project is deferred to future consideration since Unit 6 was not a focus unit.

Throughout a number of sensitivity analyses, the case labeled "2ALL" held as the most economical of all cases. All other options vary from one sensitivity to the next. However, when the gas price is dropped, either seasonally or throughout the year, when coal price is raised, or if the electricity demand is increased, the gas fired cases approach or surpass the economics of case "2ALL" and most other coal-fired cases.

From the analysis of options described above, it was concluded that extensive rehabilitation of TPP Tuzla Unit 3 through 6 and TPP Kakanj Units 5 through 7 is politically and socially viable and the economic figures of merit are very favorable. This would indicate that rehabilitation of all these units would be of greatest long-term benefit to EP BiH.

SCOPE OF REHABILITATION FOR TPP TUZLA UNIT 4

Selection of Rehabilitation Items

For each item of rehabilitation scope, implications of the deficiency are identified in the following categories:

- Safety/Environmental Concern
- Scheduled and Forced Outages

- Maintenance Expenses
- Heat Rate (Efficiency) Penalty
- Derating, Temporary and Permanent

Quantification of the implications of each deficiency was accomplished through input provided by EP BiH plant personnel and through Parsons' database for similar units with similar operational and performance problems. Improvements contributed by the correction of each deficiency are predicted relative to the expected condition of TPP Tuzla Unit 4 if it were restarted with only minimum emergency repairs.

Some of the improvements are grouped together in order to realize the full benefit from each individual improvement.

Estimates

Estimating cost for a project has always been a difficult exercise in view of changing market conditions. This exercise was compounded in the rehabilitation exercise in which the amount of definite works at the beginning is not clear.

In addition, suggested improvements to address each rehabilitation scope item and costs for these improvements were developed through input from EP BiH plant personnel, quotes from equipment suppliers, and from Parsons' database. A margin of 20% is added to each of the predicted improvement costs to cover indirect costs such as engineering and procurement and to provide a contingency.

Economic Analysis/Ranking of Options

After establishing the list of potential rehabilitation items, it is necessary to determine which of the items are cost effective. This is done by establishing a simple economic model that determines the net present value (NPV), economic internal rate of return (IRR) and discounted payback for each item. Each item is evaluated individually unless, as discussed above, certain items needed to be combined in order to realize the full benefit. The evaluation period is a nominal 15 year project life. The economic analysis of the rehabilitation options allows a ranking of options from most to least cost effective, according to the economic figures of merit.

Criteria have been established to qualify items for the rehabilitation project. Any of the following criteria qualify the item for the project:

- Significant safety or environmental issue

- IRR equal to or greater than 15%
- Payback equal or less than 5 years.

After conducting the screening analysis, it has been found that 49 rehabilitation items qualify for the project at TPP Tuzla Unit 4.

Recommended Scope of Rehabilitation

The considerations to proceed with the project had to take into account the future operational prospects and roles of the units against the economic of the investment to be committed.

For the final project analysis, the implementation of the qualifying items is divided into two stages. The two stages were developed partly based on economic benefit but also based on immediate needs, accomplished work, financial and environmental factors, and other plant priorities. Stage I is intended to include items which address particulate and NO_x emissions and items which will bring the units back to an operational and performance state which approaches the original design of the unit. Stage II is to include items to address SO₂ emissions (TPP Kakanj Unit 7 scrubber) and upgrade items to improve the efficiency and economics of the units (steam turbine modernization).

The recommended scope for the rehabilitation of TPP Tuzla Unit 4 for Stage I is presented in Table 3.

A brief summary of the economic evaluation of rehabilitation items from Table 3 is presented in Table 4.

Financial Analysis

A detailed financial model was developed for the rehabilitation project. The financial analysis section is divided into three segments. The first segment briefly introduces the methodology of assessing the projects net present value and reviews its results. The second segment reviews results of the two cases (Stage I and Stage II) and compares the cost of generation with the model tariff assumption. The third segment undertakes sensitivity analysis and demonstrates the material impact that changes in particular assumptions may have on the project profitability.

Figures 2, 3, 4 and 5 illustrate the benefits of the project for the entire EP BiH thermal power system as projected for the year 2010.

The summary of some of the predicted plant performances is given in Table 5 to compare the existing condition with re-powering of TPP Tuzla Unit 4.

Table 3. Recommended Rehabilitation Scope- TPP Tuzla Unit 4 – Stage I

Item Number from Economic Analysis	Scope Item	Selection Basis	Capital Cost (1000 DM)
1	Reconstruction of district heating.	-Environmental	3960
2	Replace furnace waterwalls with new, full membrane walls.	-Economics	11400
3	Inspections of boiler drums once every two years.	-Safety	14.88
6	Replace screen superheater tubes with U-tube design.	-Economics	5400
7	Replacement of all refractory surrounding curtain superheaters.	-Economics	Included w/ item 6
9	Replace eroded sections of tubing and install tube shields of economizer.	-Economics	120
10	Replace all regulating spray valves with an improved design for each of 4 stages. Replace liners in spray header.	-Economics	420
15	Replace superheater safety valves or all safety valves on boiler, depending on results of detailed inspection	-Safety	600
19	Replace induced draft fans with centrifugal design	-Economics	7800
20	Replace electrostatic precipitator (ESP)	-Environmental	Included w/ item 19
24	Retrofit low NOx combustion system	-Economics	1920
25	Re-tube surface condenser	-Economics	1200
34	Overhaul boiler refractory and casing	-Economics	1200
38	Install new ash handling system with dense phase conveying	-Environmental	3000
58	Install new distributed control system which includes data acquisition system and sequence of events recorder. Expand to monitor and control the electrical distribution system, coal feed system and the steam turbine. Includes new control room, field transmitters, cabling, MCCs (see previous item) and UPS	-Economics	8400
60	Install continuous emissions monitoring system	-Environmental	480
62	Overhaul of turbine generator	-Economics	2400
63	Overhaul of other mechanical equipment	-Economics	7200
64	Modernization of electrical equipment	-Economics	2400

IMPLEMENTATION OF THE PROJECT

Implementation Schedule- Rehabilitation 2001-2005

Based on the generation model planning results for option 2ALL, the rehabilitation plan of TPP Tuzla for years 2001-2005 was prepared, and is presented in Table 6. An approximate, simplified implementation schedule for the rehabilitation of Unit 4 is presented in Table 7.

Table 4: Economic Summary of Rehabilitation Project TPP Tuzla, Stage I

Capital Cost (units)	1,000 DM	57,915	Availability Improvement (hours)	1,085	Capacity Increase (MWe)	0	Part-Time De-rate (MWe)	10	Heat Rate Improvement (kJ/kWh)	1,219	Decrease in Maintenance (1000 DM)	2,880	IRR of Benefit (%)	34	Cumulative NPV Benefit (1,000 DM)	126.7	Pay Back (Years)	3.147
TPP Tuzla 4																		

Table 5. Summary of some of the predicted Plant Performances TPP TUZLA unit 4

TPP Tuzla Unit 4 (Without District Heating)		Stage 1.	Stage 2
		Base (Restart)	
Capital Cost (1000\$)		26,088	31,597
Electric Generation – Gross (MW)		0 (200)	240
Electric Generation – Net (MW)		0 (166)	220
Availability		(64%)	87.4%
Capacity Factor		0 (55.3%)	87.4%
Plant Heat Rate –LHV (kJ/kWh)		0 (12,581)	11,362
Particulate emission (mg/Nm)		0 (1500)	<150

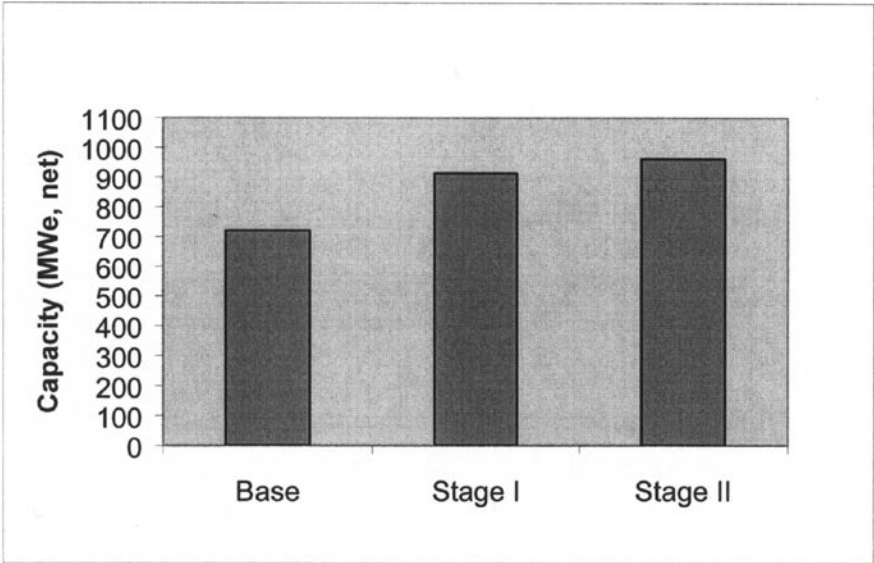


Figure 2. Capacity of Thermal Power Plants

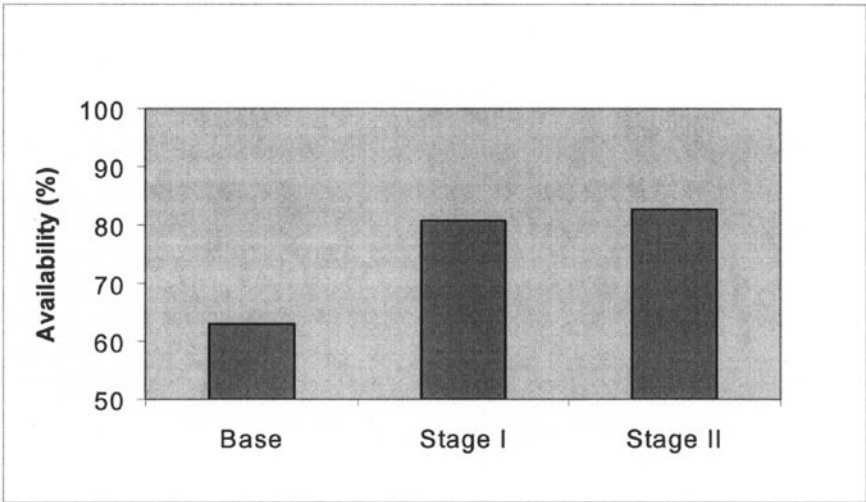


Figure 3. Average Availability

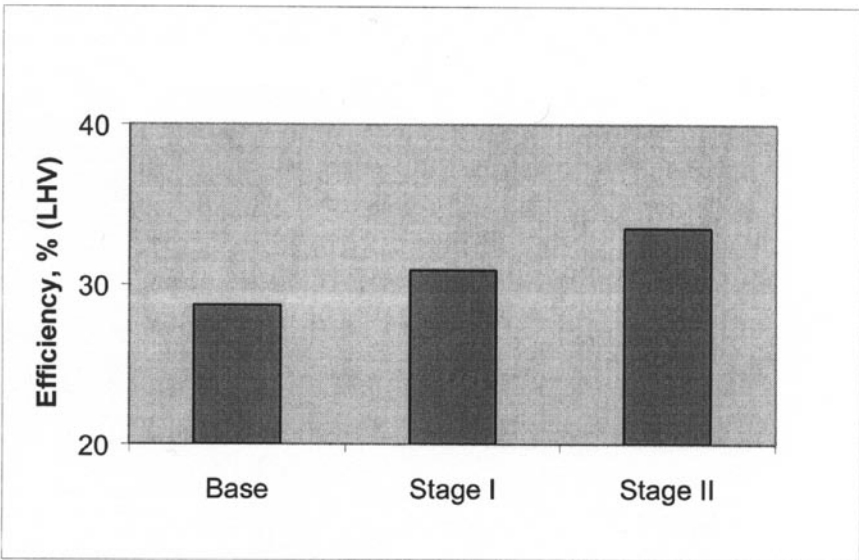


Figure 4. Average Plant Efficiency, LHV

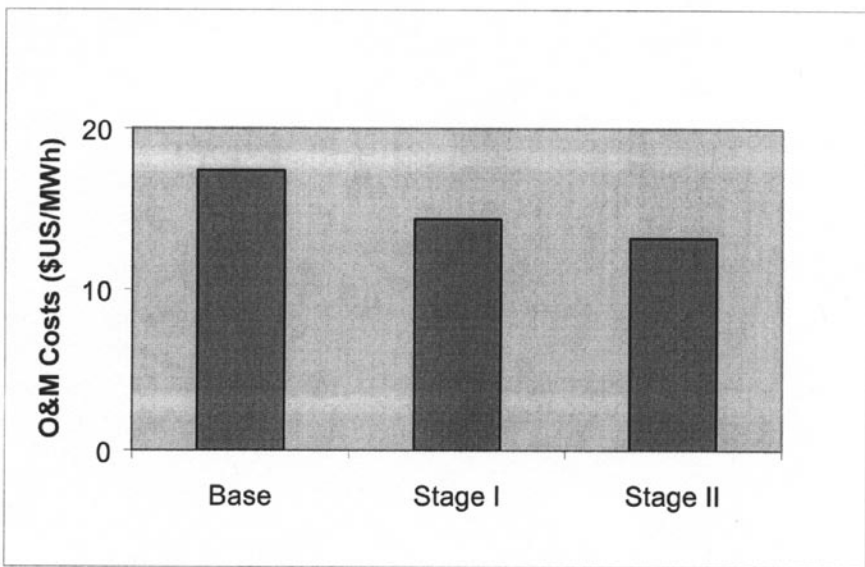


Figure 5. O&M Costs (Non-fuel)

Implementation Criteria

The consideration to proceed with the project had to take into account the future operational prospects and roles of the unit against the economics of the investment to be committed. The recommended scope for the rehabilitation of TPP Tuzla Unit 4 for Stage I had formed the framework of the contract.

PROJECT TARGETS

The Stage I of rehabilitation as recommended is expected to enhance the project objectives/benefits, as follows:

- Ensuring the new (recoverable) capacity of 200 MW for electric power production and necessary reserve in the electric power system of Bosnia and Herzegovina (BiH).
- The economic life of the plant had been extended by a minimum of 10 years.
- The benefits to be accrued from the new system for control and instrumentation should facilitate higher availability, efficiency and reliability by effective plant monitoring, control and protection.
- By reconstruction of electrostatic precipitator reduce particulate emission less than 150 mg/Nm.
- By completing the project of process heat generation (district heating) ensure additional thermal capacity of 142 MW_t and increase the overall unit efficiency in combined heat and power generation.
- The benefits to be accrued from the replacement of hydraulic slag handling system with modern pneumatic ash handling system (reduce the amount of pollutants release from TE Tuzla).

TENDER PACKAGING AND CONTRACTING

For the implementation of the project it was decided to use the procedure of the World Bank for limited international bidding (LIB). Rehabilitation items are grouped according to technological units for which technical specifications and tender documents have been prepared. Design details have not been specified in the technical specifications. This has been left to the experience of contractors who deliver the equipment that has to comply in all aspect with the basic performance requirements.

Technical specifications cover: services connected with design of project, adopting and compatibility of new deliveries with other systems (functional units), erection and commissioning.

Invitation for delivery of bids has been sent to all suppliers from the short list of bidders (EP BiH prepared the list) which also included the original suppliers of equipment.

Typical examples of agreed packages are:

- Replacement of controls and instrumentation equipment
- Reconstruction of electrostatic precipitator
- Replacement of electrical equipment
- Ash handling system
- Reconstruction of district heating
- Overhaul of turbine generator including some modernization
- Rehabilitation of boiler (tender was issued in March 2001)-Contractor 'RAFACO' Poland-the original boiler supplier.

PROBLEMS ENCOUNTERED DURING IMPLEMENTATION

During the implementation of the project, several problems were encountered which caused the project to be delayed. Among the most serious problems encountered which necessitated the re-evaluation of the cost benefits of the project are described briefly below:

1. During the audit phase, it was not practical to inspect the boilers in detail by removing the insulation and such, due to the time required to carry out such detailed inspection. Instead, the condition of the boiler was inferred from inspection and study of the plant maintenance and break-down records. When the plant was actually shutdown and detailed inspection carried out, some unexpected technical problems related to the boiler internal pressure parts were encountered.
2. When the scope of work was identified and classified accordingly, the marginal cost of including the items into the scope had to be evaluated. During this procedure, calculated risk based on engineering judgments had to be taken. However, when work was actually carried out, it became clear that certain judgments were in error and rectification works were necessary.

3. It was necessary to define all inputs for the use of modern control and instrumentation equipment supplied by Siemens. However, after detailed drawings were made, it was necessary to carry out some modifications.
4. Deterioration of the plant was also encountered which occurred between the period after the audit was carried out and the time of the actual work. Some of the defects identified earlier during the audit, and not included into the final scope of work, had to be included as additional works in order to achieve the full benefits.

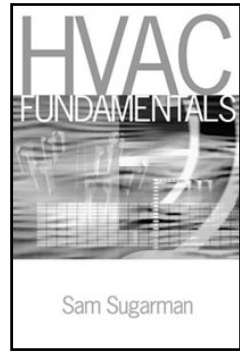
ACHIEVEMENTS OF THE PROJECT

Despite some of the serious problems and setbacks encountered during implementation of the project, the results obtained after performance testing and through the operation of the rehabilitated unit have shown that the primary objectives of the project have been achieved.

- The project returned Unit 4 to commercial service, which had been out of service for 10 years. Unit 4 is in operation without any problems, achieving a nominal rating of 205 MW of electrical power at generator terminals when operating under condensing mode. The overall efficiency in condensing mode is 32%. A nominal rating of the unit is 182 MW_{el}/142 MW_v when operating under CHP (cogeneration) modes. (The overall efficiency is 9,891 KJ/kWh).
- From the previous degree of boiler efficiency, which was 83%, and by bid requested 87%, we reached 89.46%. That is 2.46% more than the bid predicted. This means that (with this effect) there is saving of 3.5 million KM/year.
- Considering the technical and financial complexity as well as the scope of the project of modernization and empowering of block 4, 200 MW, the due date of 14 months, (starting with signing of contract for boiler until the first synchronization of the block) is respectable.
- The entire project is outlined, led and empowered by JP EP BiH and TE Tuzla. This means that the entire investment, technical and tender documentation has been carried out. Bids were collected and the most favorable bidders were chosen based on methodology of the World Bank.

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By Michael F. Hordeski

This comprehensive reference addresses the diverse topics that form the backbone of energy conservation, in a time-saving dictionary format. Entries include a broad range of important topics, covering such areas as advanced power system infrastructure, power options and configurations, systems of generator backup, redundancy, capacity, power quality problems, power protection, computer-controlled systems, auditing, energy reduction, lighting systems, cogeneration, waste heat recovery and HVAC systems. Each entry is one to several pages in length, and covers critical issues and solutions in many important emerging areas of the energy efficiency field.

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- We have completed the training of the block crew—experts for maintenance and operations of functional trials and tests.
- When it comes to ecological work that has been done on blocks, measurements have been completed and from the 100 mg/Nm³ dust emission that has been requested by the agreement emission value of 35 to 70 mg/Nm³ was achieved. Also out of 450 mg/Nm³ NO_x emission that was requested by the agreement the emission value of 354 mg/Nm³ was achieved.
- By completing the project of ash removal and slag handling, many results have been achieved. Savings in water, energy and space for the deposit of ash and slag have been achieved. Cement Factory Lukavac receives 400 tones of ash daily from this block. Based on the protocol about intentions signed with the cement factory, connected with the expansion of capacity, the preliminary agreement was achieved in 2003 we will deliver 800 tons of ash per day and, in year 2004, 1600 tons per day
- In spite of unplanned additional work discussed earlier in this article, the project was completed within the budget of \$170 US Dollars/kW.

CONCLUSION

The adaptation of old technologies at lower operational cost and greater flexibility could be considered as the course of action to be taken by many facilities thereby improving profits, making operations more flexible and environmentally friendly. These changes, with lowest possible investments, are due to prevailing uncertainties and short-/medium-term analyses.

Through plant rehabilitation, there is the technology for various improvement actions to extend the useful life and improve performance of existing plants, which can contribute significantly towards the objective of supplying electricity at least cost.

There must be general awareness of technical and financial implications rising from forced outages, low availability and heat rates as these tell-tale signs, without proper maintenance will result in loss in generation capacity, premature aging and perhaps operator frustration.

One way for utilities to respond to competition is to look for other outlets of development besides electricity sales. Typical measures are the conversion/modification of coal based extraction condensing power plants to CHP plants, which offer industry other energy services such as heat and steam in addition to electricity.