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IMPROVING MACEDONIA'S POWER SYSTEM THROUGH REHABILITATION OF ITS BIGGEST HPPs

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ABSTRACT

At present, the installed hydropower capacity in Macedonia is 30% of the total installed capacity. The six biggest HPPs in Macedonia are: HPP Vrutok, HPP Raven, HPP Vrben, HPP Globocica, HPP Tikves and HPP Spilje, which represent 91% of the country's hydropower capacity. Rehabilitation and life extension of these hydro power plants is very important. This is because the hydropower plants are generally fairly old, older than most of the thermal generation capacities. Moreover, these plants play a vital role in the Macedonian Power System, providing peaking capacity, reserve capacity and frequency control.

KEY WORDS: Hydro power plants, rehabilitation, power generation.

1. Introduction

The **Electric Power Company of Macedonia (ESM)** is the public electric power utility of Macedonia, responsible for the generation, transmission and distribution of electricity in the country. The ESM is operating as an independent electric power system connected in a parallel operation with the other electric power systems in the isolated part of UCTE and has recently become a full member of the UCTE interconnection.

In 1998, ESM received a loan from the International Bank for Reconstruction and Development *(IBRD)* for the cost of the Power System Improvement Project, a part of which is the partial rehabilitation of the six largest HPPs in the Republic of Macedonia. This rehabilitation is very important for the whole power system of the republic. The investments are to replace worn out equipment or totally obsolete equipment which is inefficient and for which no spare parts are available.

Macedonia has an installed hydropower capacity of 1335.8 MW, which is 30% of the total installed capacity. The remaining 70% is thermal capacity.

The project financing is done by the World Bank's loan and by two additional grants: from the Japanese Government, and from the Swiss Government.

In the realization of the project, the companies Electrowatt Engineering (EWE), Switzerland, and Electricité de France (EdF), France (as Joint Venture EWE/EdF), participated as consultants hired by ESM during the bidding documents preparation phase, as did the Macedonian company, GEING, as a local partner of the JV EWE/EdF.

The refurbishment program is spread over six years, from 1998 to 2004.

2. Rehabilitation of HPPs

The HPPs covered by this project are: HPP Vrutok *(4 units: two units put in operation in 1957, two units put in operation in 1973);* HPP Raven *(3 units: two units put in operation in 1959, one unit put in operation in 1973)*; HPP Vrben *(2 units: put in operation in 1959)*; HPP Tikves *(4 units: two units put in operation in 1968 and two units in 1981)*; HPP Spilje *(3 units: all of them put in operation in 1970);* and HPP Globocica *(2 units: put in operation in 1965).*

The **Mavrovo HPP Complex** hydro scheme is composed of three powerhouses: Vrutok, Vrben and Raven, arranged in a cascade; together with the Mavrovo dam and reservoir, and a network of feeder canals and tunnels to catch the water coming from the nearby mountains. The water is collected at levels higher than 1230 m, and the area is 520 m^2. This HPP complex is located in the northwestern part of Macedonia.

The first powerhouse in line is **Vrben** at 12.8 MW. This surface type HPP is situated 33 km west of Gostivar. This hydro power plant is of the running type. Water emerging from this powerhouse goes into the multi-year Mavrovo reservoir and then to the two power stations of Vrutok and Raven that are supplied in series by the same penstock. HPP Vrben is connected to the HPP Vrutok by a

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35 kV transmission line and through a 35/110 kV transformation it delivers the electricity to the Macedonian power system.

The **Vrutok** hydropower plant is an underground cavern plant, located 7 km west of Gostivar. The plant is a peaking type with installed capacity of 150 MW. HPP Vrutok is feeding into 110 kV transmission line of the Macedonian power system.

The **Raven** surface hydropower plant is located 5 km west of Gostivar. The plant is the running plant, with an installed capacity of 19,2 MW. The electricity produced in this plant at voltage level 6,3 kV is transformed to voltage level 35 kV and conveyed to the Vrutok plant from where it is delivered to the Macedonian power system through two 35 kV transmission lines.

The **Globocica** surface type HPP is located in the southwest of the country on the Black Drim river, 22 km north of the town of Struga. It has been in operation since 1965. Installed capacity is 42 MW, and average annual output is around 187 GW. The plant is feeding into the Macedonian power system at 110 kV and 35 kV level. It is in need of rehabilitation.

The **Spilje HPP** is a surface type plant, located on the Black Drim river downstream of Globocica. The plant is utilizing water from the Black Drim river catchment retained in the lake of Debar. Spilje plant is situated in the western part of the country, about 5 km from the city of Debar. In operation since 1969, its installed capacity is 84 MW, and the average annual generation is around 300 GWh.

Table 1. HPPs basic data

	Number of units	Rated power (MW)	Annual generation for 2000 (GWh)	Year of installation	Plant type	Reservoir volume (10^6 m^3)	Turbine type	Dam
Vrutok	4	150	376.8	1957/1973	Reservoir	277	Pelton	earth-fill type (H=62m)
Raven	3	19.2	43.2	1959/1973	Run of river	/	Francis	/
Vrben	2	12.8	31.4	1959	Run of river	/	Francis	/
Globocica	2	42	178.2	1965	Reservoir	15	Francis	rock-fill dam with clay core (H=90m)
Tikves	4	92	128.3	1968/1981	Reservoir	272	Francis	rock-fill dam with clay core (H=113.5 m)
Spilje	3	84	289.9	1970	Reservoir	212	Francis	rock-fill dam with clay core (H=112 m)

The total capacity of this hydro scheme is 182 MW, which is a little less than half of ESM's installed hydro capacity of 435,8 MW (including the small HPPs). This hydro scheme typically generates around 500 GWh, about 80% of which comes from the largest plant, Vrutok. Generation from this hydro scheme is typically just under 50% of the total hydropower production in Macedonia and is used primarily for peaking purposes. The powerhouses in the scheme were built back in the 1950's and need to be rehabilitated in order to increase efficiency and reliability.

The **HPP Tikves**, a surface-type powerhouse, is located below the Tikves dam on the Black River, about 12 km west from the city of Kavardarci, in the southwestern part of Macedonia. The first two units have been in operation since 1968, and the second two units since 1981. Total installed capacity is 92 MW, and average annual generation is about 185 GWh. The plant is primarily used for peaking purposes, though it is also run when irrigation water is needed downstream. The plant is feeding into the Macedonian power system at 110 kV level. Due to age, it is in need of rehabilitation.

The Debar reservoir behind the Spilje dam has moderate storage capacity and the plant operates both as a base load unit and for peaking purposes. The plant is feeding into the Macedonian power system at 110 kV level. Some rehabilitation is required.

The main objectives of this project are:

- to improve the operational efficiency of the existing hydropower plants, which would result in greater hydropower generation, reduction in system costs and a reduction in carbon dioxide emissions due to reduced thermal generation;
- to expand the generating capacities of the major hydropower plants through rehabilitation , which should enable the country to better meet its peak electricity demands, help stability frequency and reduce the likelihood of brown-outs and black-outs;

- extension of the useful operating life of the hydropower plants through replacement and/or repair of worn-out plant/unit components.

Procurement of the equipment is set in five separate packages, divided by the type of equipment: two mechanical equipment packages (#1 and #2) and three electrical equipment packages (#3, #4 and #5):

Package #1: Turbine runners, turbine bearings and generator bearings, governors, inlet valves;
Package #2: Butterfly valves including accessories and control systems;
Package #3: Generators, excitation system and voltage regulation;
Package #4: Control system, protection and LV auxiliaries;
Package #5: Switchgear and controlgear 220 kV, 110 kV and 35 kV substations.

Most of the units treated for rehabilitation have been in operation more than 30 years, and some of them more than 40 years, which is beyond the useful life of a hydropower plant, and are in need of major rehabilitation and modernization to meet system operating requirements.

All the plants have been very well maintained throughout their existence. Considering the age of the installation, the equipment is in reasonably good condition. The plants are largely autonomous and operate more as separate entities than common parts of a utility.

The hydropower plants, according to the Feasibility report [1] prepared by Entreprises Electrique Fribourgeoises (EEF), are facing "equipment dilapidation" due to age as well as obsolescence. As a result, their generation, capacity, reliability and safety are decreasing. Rehabilitation of these HPPs is the least cost means of providing the republic with peaking capacity. Furthermore, as these plants continue to deteriorate from age they will become rapidly more unreliable, depriving the republic of its required peaking capacity and leading to expensive outages. The only near term alternative, new gas fired peaking units, would be much more expensive and would increase the country's already high reliance on imported fuel and energy. In emergencies power can sometimes be obtained from the republic's neighboring countries.

The main benefits form rehabilitation of the HPPs are:

- *Increased capacity*

The reconstruction of the turbines at the hydropower plants adds significantly to the generating capacity of these plants by increasing the efficiency with which the water from the penstocks is used. This additional capacity will add to system reserves and improve primary and secondary regulation. ESM has estimated the total turbine capacity increase will be about 40 MW.

- *Increased generation*

The increase in hydropower generation due to increased efficiency of the turbines is estimated as 13,7 GWh per year. This is a gain of 1,9% on average for the six plants and assumes an average year with 730 GWh of HP generation from these plants. Of course, this is a conservative assumption. This additional power would be largely peaking power and generated in the winter when the demand for power in the Republic of Macedonia is at its peak due to the heating load. It would replace either power generated from thermal power plants in Macedonia or power swaps with neighbors.

- *Operating costs*

The investments in the HPPs will significantly reduce operating costs, mainly repair costs, by replacing worn out or obsolete equipment. Current equipment is expensive to maintain with the cost of repairs (mostly spare parts). It is assumed that the reduction in the costs of repairs would continue for about 10 years, and then repair costs would again start to rise, reaching their current level in about 20 years.

- *Outages*

Because of the age of the equipment, outages of HP generating units are expected to increase rapidly unless these units are rehabilitated. As a first approximation, EEF assumed that one power plant out of six would be out of operation one month per year, if no rehabilitation were undertaken and that this risk would be reduced by two thirds if the plants were rehabilitated. This implies that, as a result of rehabilitation, the lost generation from outages of HPPs would be reduced by about 7 GWh per year. If in fact this electricity was unserved energy (i.e. it resulted in brown outs or black outs) the value would be very high. This assumes that the electricity would have been replaced by electricity generated from thermal power plants or by swaps with neighboring countries.

The project will have little impact on the environment and the little impact it has will be generally favorable. The project will increase hydropower production by about 13 GWh. This extra hydropower generation will replace generation which would have come from burning fossil fuels, either lignite or heavy fuel oil, both of which create emissions of carbon dioxide and sulfur dioxide. Thus the additional hydropower production will reduce slightly ESM's overall emissions of carbon dioxide and sulfur dioxide.

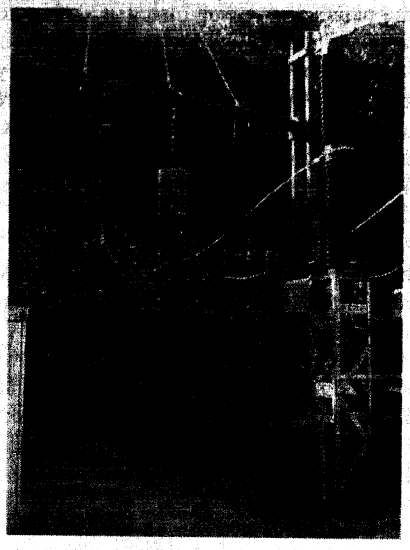
Current situation of the project

The Loan Agreement was signed in 1998, when the activities regarding the rehabilitation of the HPPs started. According to the World Bank's rules and procedures, ESM carried out bidding procedures for all five procurement packages. The bidding process for all five procurement packages has ended, and the contracts with the lowest evaluated bidders have already been signed.

At present, the project is in the equipment implementation phase.

The entire equipment implementation is scheduled and coordinated by the Electric Power Company, taking into consideration that plant stoppages should be done with no impact (disturbance) on the operation of the Macedonian power system as a whole.

ESM has commenced implementation of the rehabilitation of switchgear and controlgear 220 kV, 110 kV and 35 kV substations. The first phase of this implementation has finished *(June-September 2001)*, and with this phase, the 110 kV and 35 kV substations in the biggest plant HPP Vrutok have been 50% rehabilitated; the implementation of the equipment will continue in the ensuing phases.



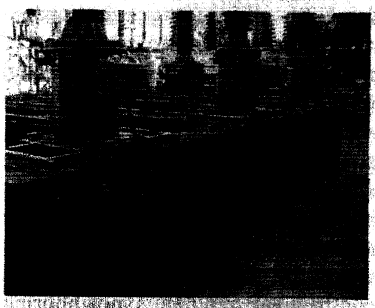


Fig. 1. Partial rehabilitation of the 110 kV switchgear in HPP Vrutok

3. CONCLUSION

Rehabilitation and life extension of the hydro power plants is given the highest priority in the whole Power System Improvement Project.

At the present time, hydro- power presents only 15% of the total power production in Macedonia (85% is thermo power production). Also, only 25% of the total hydropower potential of Macedonia is being used (in other countries min 50% of hydropower potential is being used). Furthermore, to ensure a stabile power system 30% of the total power production is required to be hydropower. With the realization of this project, greater hydropower production is expected. It is also expected that HPPs will become a more vital part of the Macedonian power system. This is also beneficial from an environmental aspect, due to greater usage of renewable energy resources.

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[1] Entreprises Electrique Fribourgeoises (EEF), *Feasibility Report*, 1996.

[2] JV EWE/EdF, *Report on recommendations, findings, design and planning of the rehabilitation works,* 1998.