Analyzing Impacts of Regional Power Markets on the Operation of Hydropower Plants

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ABSTRACT

The paper presents a modeling approach for the assessment of the operation of hydropower plants in a regional electricity market. It provides a comparison of hydropower generation patterns obtained for the isolated and regional market operation scenarios for the power system of Bosnia and Herzegovina. The results are part of a recent eight-system power market study analyzing a future regional electricity market in Southeastern Europe. The results obtained from the study confirmed that hydropower plants play an important role in Southeast Europe and would bring significant benefits to the development of a regional electricity market.

Introduction

Southeast Europe is moving rapidly toward the creation of a regional electricity market. Argonne National Laboratory, in association with Montgomery Watson Harza, recently carried out a study "Role and Value of Hydro and Pumped Storage in Southeast Europe,"[1] sponsored by the U.S. Agency for International Development. The objective of the study was to investigate potential benefits of a regional electricity market in Southeast Europe and possible impacts on the operation of hydro and pumped-storage plants in the region. The analysis focused on the power market situation in 2005, which is, according to the Athens Memorandum of Understanding [2], the target year for the operation of a regional electricity market for industrial and large (nonresidential) consumers.

The study modeled the operation of electric power systems of seven countries in Southeast Europe and built upon the previous studies [3–7] performed by Argonne in the region. Included were the electric utility systems of Albania, Bosnia and Herzegovina (B&H), Bulgaria, Croatia, Macedonia, Romania, and Serbia and Montenegro. Turkey also participated in the project as an observer country but was not modeled. The analysis was performed using the Generation and Transmission Maximization Program (GTMax) [8, 9] developed by Argonne.

The study also looked at the variability of water inflows in different countries of the region and found that there is more hydrological similarity than diversity. The typical pattern for most countries consists of very high inflows in spring and very low inflows in late summer. The study concluded that when the regional market starts operation practically all of the countries can expect lower net energy supply costs. In general, regional market operation would allow for more cost-effective electricity production in the region by increasing the utilization of the most economical generating units and better optimization of hydro and pumped-storage dispatch. The study also shows that, in the regional market operation, hydro and pumped-storage plants can provide an even greater amount of ancillary services than if the utility systems operate independently. The results obtained from the study are now being used for regional transmission planning studies to evaluate proposed investments into new transmission interconnections.

This paper presents some of the results of the study focusing especially on the electric power system of B&H.

Methodological Approach

To estimate the role and value of hydropower plants in the regional electricity market, the GTMax analysis was performed for two sets of scenarios: (1) independent operation of individual electric power systems, and (2) integrated operation in the regional electricity market. The analysis was performed on an hourly basis for typical weeks in different seasons of the year (winter, spring, summer, and fall). To capture the variability of hydro inflows and their influence on hydro generation, the analysis was performed for three hydrological conditions: wet, average, and dry.

Figure 1 shows a simplified topology of the regional network that was configured for the study. GTMax computes locational marginal prices (LMPs) at various locations within the power system and at interconnection points with other systems. Market-clearing prices are dependent on the supply/demand equilibrium as well as on the transfer capabilities of the transmission network. In the study, market clearing prices were assumed to be the marginal cost of delivering energy to a specific location. To investigate the impacts of a regional electricity market on the operation of hydropower plants, the power market analysis compared the operation of individual utility systems versus their integrated operation in a regional electricity market. While the operation of hydropower plants in individual utility systems is mostly driven by the loads, under the integrated regional market scenario the LMPs provide price signals for the operation of hydropower plants. Using LMPs as a driving factor, hydropower plants with regulation capabilities are trying to maximize their output during times of high LMPs, thus maximizing the value of their generation.

The differences in LMPs and total operating costs in the region obtained for the above two scenarios provide an estimate of the economic benefits of a regional electricity market. Also, by analyzing the operation of individual hydro and pumped-storage power plants and the value of their generation, it is possible to provide an estimate of their role in the regional electricity market compared with their operation in the individual power systems. The expected "value of water" in hydro reservoirs is calculated based on the system load and available thermal generation. GTMax computes the value of water in each reservoir and in each hour during the week based on the hourly LMPs in the system or, when there is transmission congestion, on the LMPs in the market hubs to which the hydropower plants supply power. Therefore, the value of hydro generation is determined as the avoided cost of thermal generation (or imports) that would have been loaded instead of hydro to supply the demand.

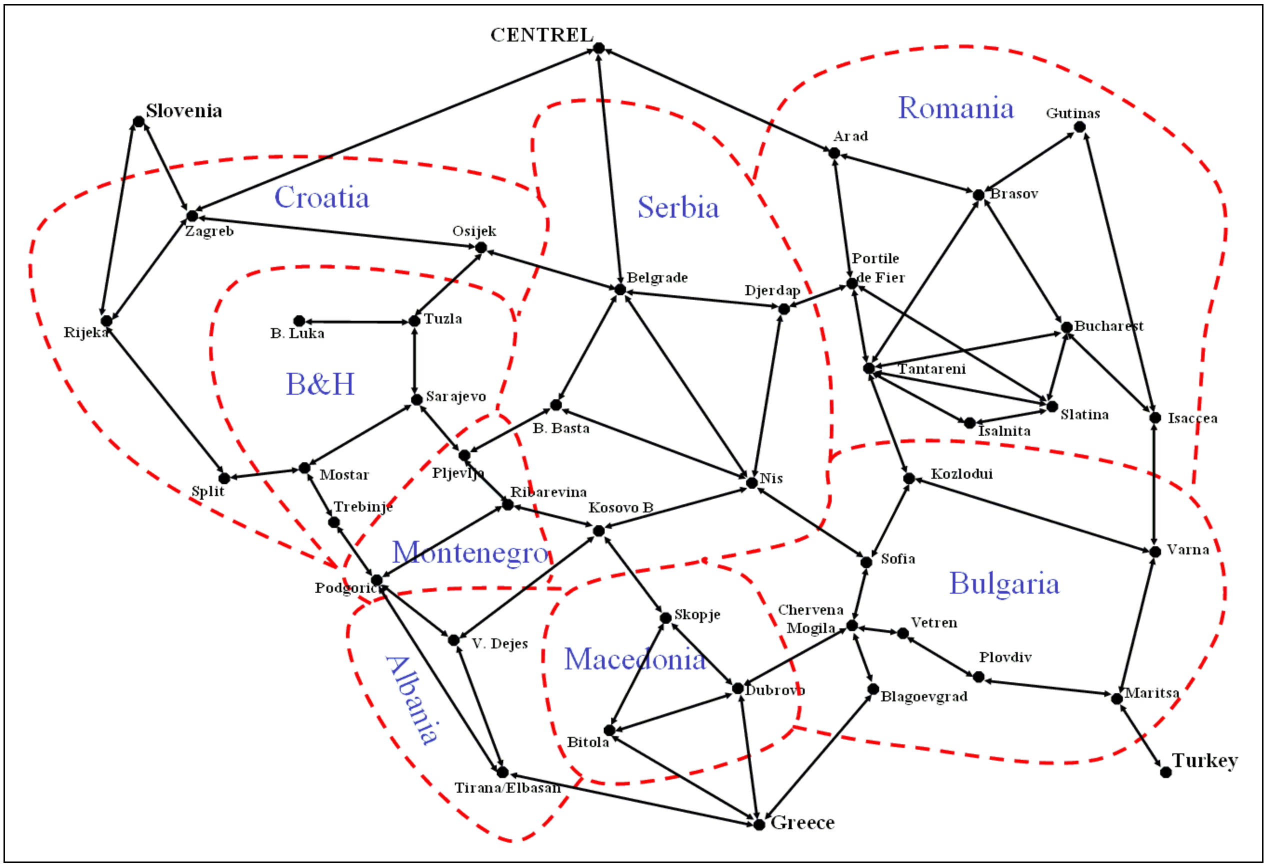


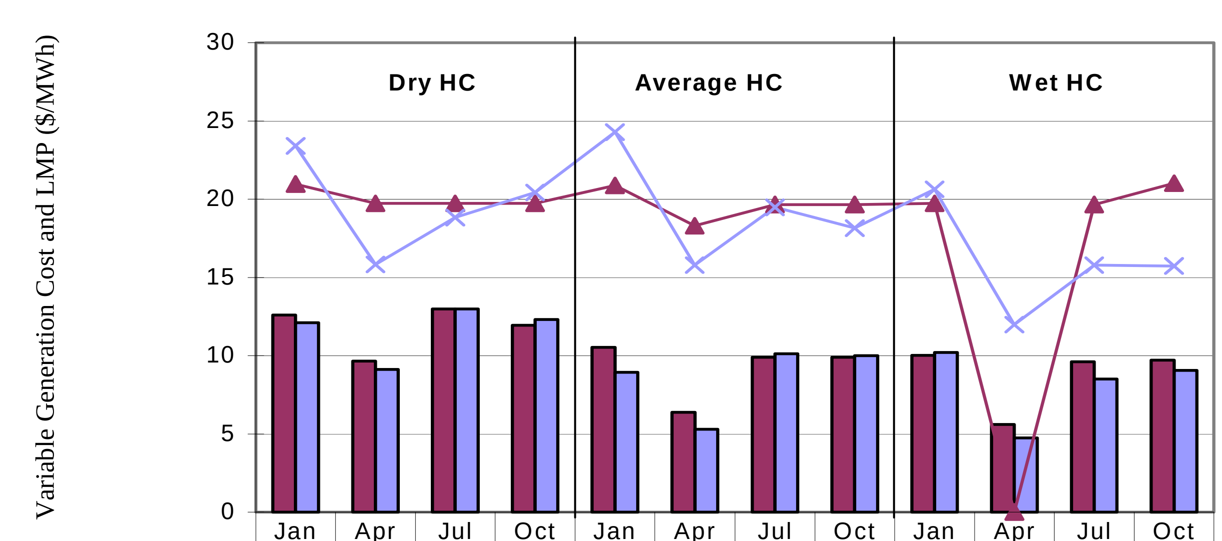
Figure 1: Simplified GTMax Representation of Regional Electricity Network in 2005

Results for the Electric Power System of B&H

There are three independent electric power companies operating in B&H. At the end of 2003, the total installed capacity in B&H was 3,999 MW, of which 2,042 MW in hydro and pumped-storage power plants, and 1,957 MW in thermal power plants. No new generating units, either thermal or hydro, are expected to be commissioned by 2005. The net electricity generation in B&H amounted to 10,770 GWh in 2002, which is about 20% lower than electricity generation in 1990 [10, 11].

One recent development strategy study for the energy sector in B&H shows that the existing electric power plants, with planned rehabilitation and modernization, can satisfy the electricity demand in B&H at least until 2010. The rehabilitation of existing generating facilities was found to be more economical than the construction of new generating capacity. In the last several years, B&H has been exporting on average about 1,500 GWh annually.

Figure 2 shows that variable electricity generation costs in B&H are rather low under both the individual and regional market scenarios. Under the individual system operation scenario, the resulting LMPs are relatively stable, amounting to about 20$/MWh, except in April under wet hydrological conditions. LMPs drop to zero because of hydro spillages caused by rather high water inflows in spring. High water inflows cannot be easily accommodated by a relatively small power system in B&H if operating in an isolated mode and without the possibility of exporting surplus energy to neighboring systems. A typical hydrological pattern in B&H is illustrated in Figure 3, showing average monthly water inflows for several hydropower plants on the Neretva river.



	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
VGC-I	12.6	9.65	12.99	11.95	10.51	6.36	9.88	9.88	10.03	5.6	9.61	9.7
VGC-R	12.09	9.12	12.97	12.3	8.93	5.28	10.11	10	10.21	4.73	8.51	9.06
LMP-I	20.98	19.72	19.72	19.72	20.87	18.31	19.67	19.67	19.72	0	19.67	21.01
LMP-R	23.4	15.83	18.83	20.44	24.3	15.78	19.49	18.15	20.63	11.99	15.78	15.73

Figure 2: Comparison of Average Costs of Electricity Generation and LMPs for Individual and Regional Market Operation

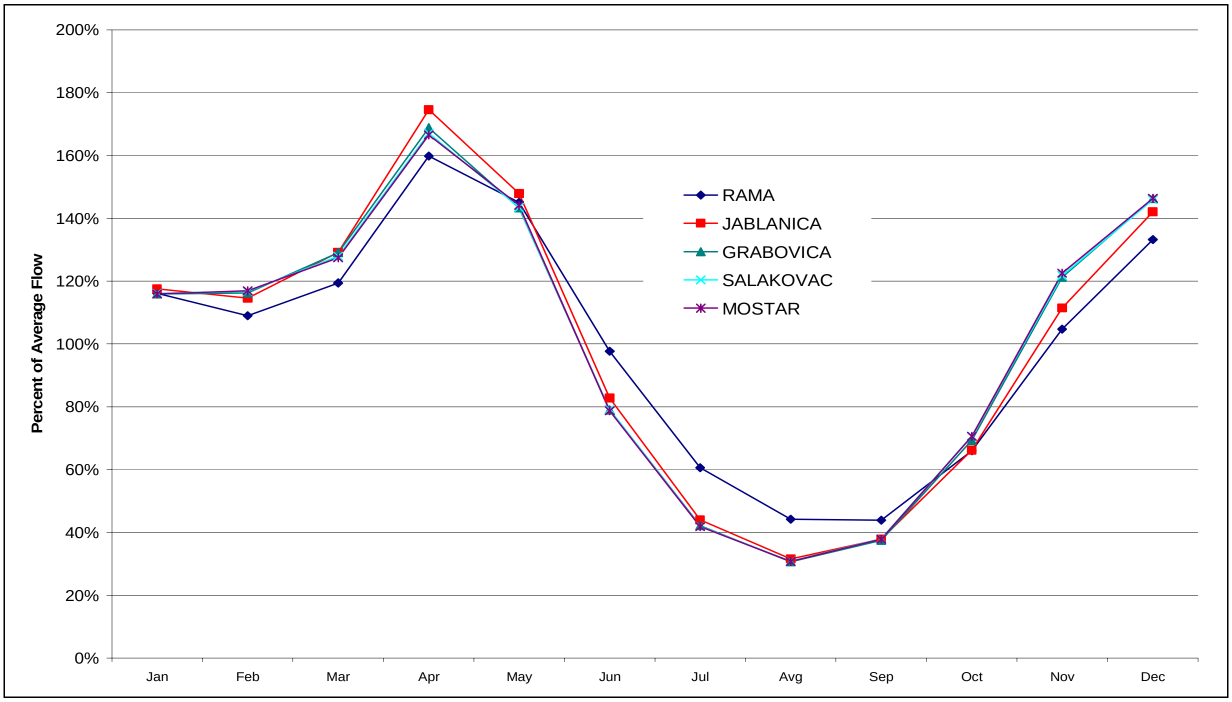


Figure 3: Average Monthly Flows for Hydropower Plants on Neretva River

The LMPs obtained under the regional market scenario (Figure 2) show more fluctuation, with the highest prices in January and the lowest in April. Due to the hydrological similarity, there are usually high water inflows in spring in the entire region, resulting in relatively low LMPs in April. Because of the larger size of the regional system and the power transactions that are possible among the utility systems, it is much easier to accommodate high water inflows in spring and the LMPs never fall to zero.

Figures 4 and 5 compare system operation under the individual and regional market scenarios in the third week of January 2005. Under the individual operation scenario, the power system of B&H satisfies its own load, with the thermal generation supplying between 700 and 800 MW in all hours, while the remaining load is met by hydropower plants, which also perform most of the load–following duties. The LMPs are relatively stable around 21 $/MWh during the day and decrease slightly to about 20 $/MWh during the night.

Under the regional market operation (Figure 5), the higher daytime LMPs provide an incentive for electricity exports. In this case, the B&H power system produces significantly more electricity than required by its own internal load. The output of baseload thermal generation is raised to between 1,100 and 1,400 MW, while hydropower plants provide most of the electricity for export. The daily pattern of hydro generation is now also different, with most of the electricity produced during the day when LMPs in the regional market are about 25$/MWh, with only little hydro generation during the night (mostly mandatory minimum generation and run-of-river hydro plants).

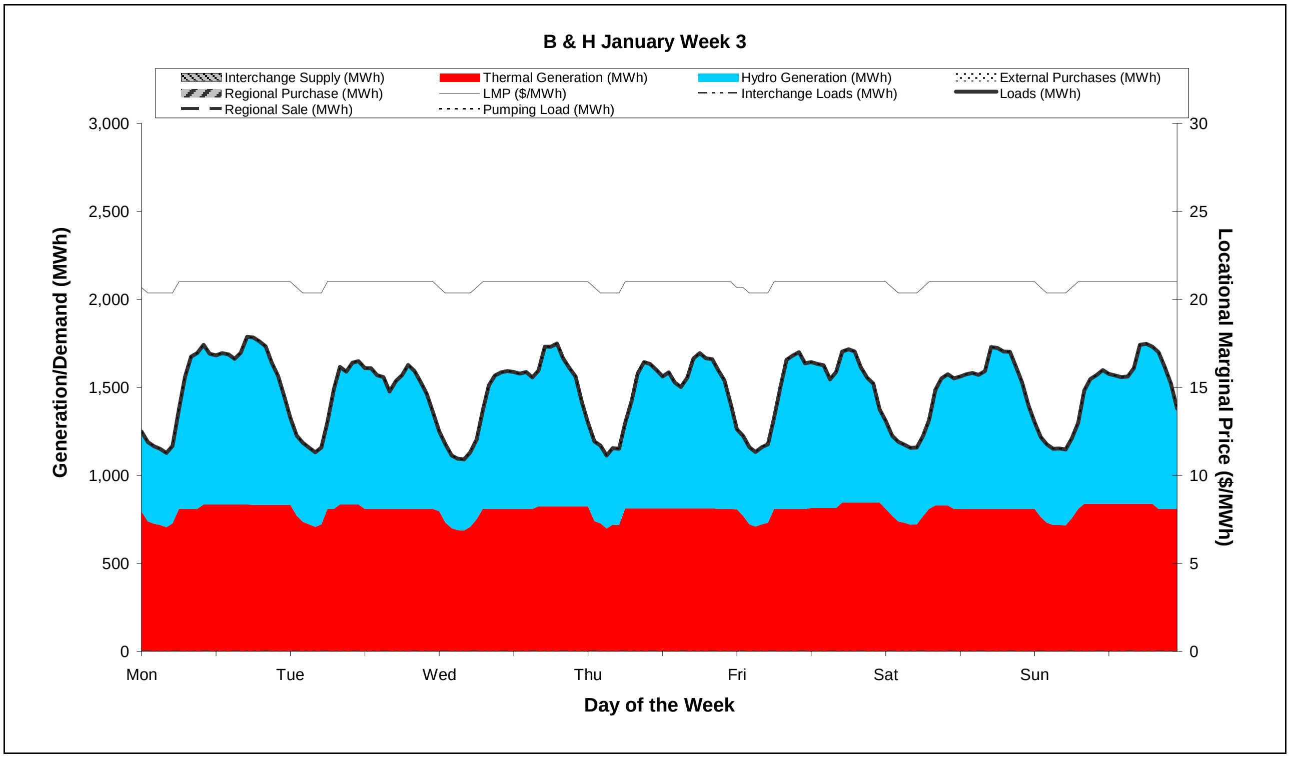


Figure 4: Individual System Operation

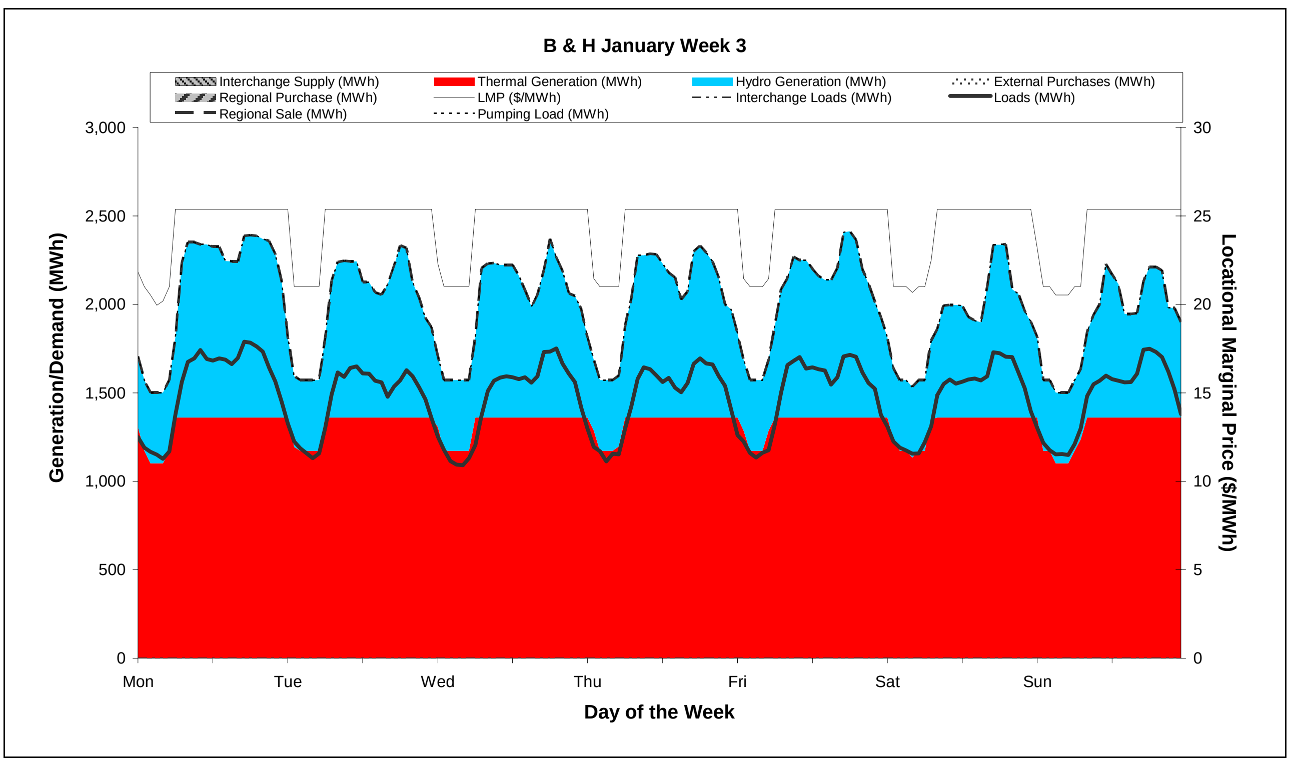


Figure 5: Regional Market Operation – Higher LMPs Provide Incentive for Exports

This shift in hydro generation is even more obvious when comparing the generation profiles of individual hydropower plants. Figures 6 and 7 provide daily generation patterns of one storage hydropower plant (HPP Rama) under the individual and regional market scenarios, respectively.

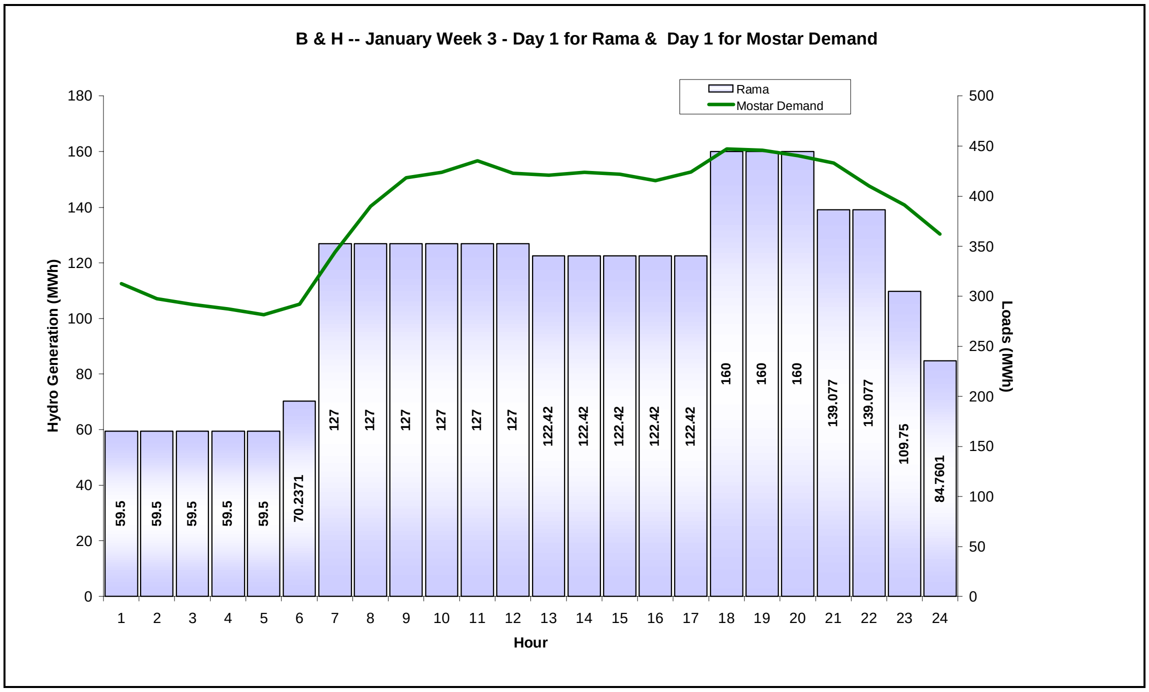


Figure 6: Individual System Operation – Operation Follows Daily Load Profile

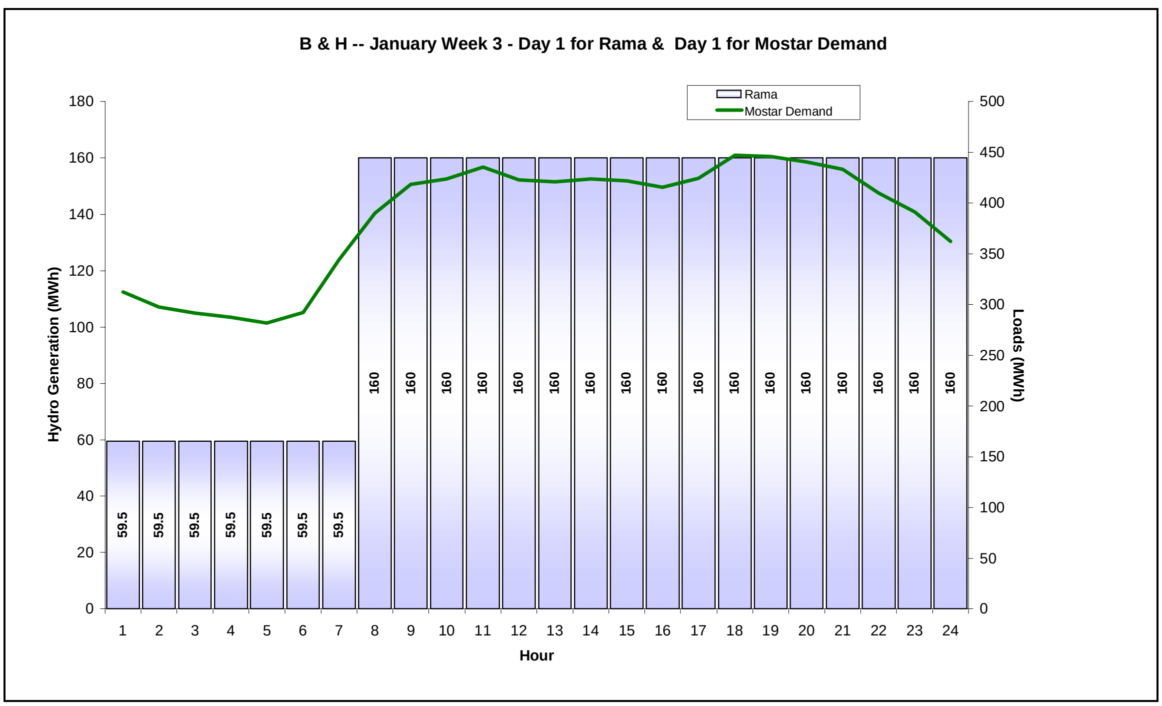


Figure 7: Regional Market Operation – Operation Influenced by LMPs in the Regional Market

Under the individual system operation (Figure 6) the generation of HPP Rama clearly follows the system load, with the power output varying from hour to hour according to the load profile. On the other hand, if the same day is simulated under the regional market operation scenario (Figure 7), the operation pattern of HPP Rama is much simpler and consists of only two steps: high power output during the high-LMP period (most of the day and evening) and low power output during the low-LMP period (night). This operation profile clearly follows the LMPs in the regional electricity market (Figure 5), thus maximizing the value of hydro generation by producing as much as possible during the high-LMP period. The simulation takes into account the storage limitations of hydro reservoirs, as well as the net transfer capabilities of transmission interconnections that are used for power transactions among the utility systems.

B&H is preparing for the regional market operation [12]. Numerous rehabilitation projects of the existing thermal and hydropower plants are underway, with the goal of increasing their efficiency, availability, flexibility of operation, and reliability. All of these are necessary conditions for a successful market operation and competitiveness.

It is also important to mention that B&H has a significant hydro potential still available for development. The total remaining hydro potential that can be economically utilized is estimated at about 17,000 GWh/year. On the other hand, the already utilized hydro potential amounts to about 8,900 GWh/year, which is only about 34% of the total hydro potential in the country. An aditional and very important source of electricity generation in B&H is small and mini hydropower plants. Their development is considered very desirable because of the relatively small investments, short construction times, low maintenance costs, and increased security of electricity generation for local consumers.

The utilization of the remaining hydro potential is one of the important goals for the economic development in B&H. Hydropower plant candidates for construction in B&H are: Konjic (120 MW), Vrhpolje (71 MW), Ustikolina (45 MW), Caplje (12 MW), Glavaticevo (170 MW), Mostarsko Blato (80 MW), Tihaljina (25 MW), Buk Bijela (450/320 MW), Foca (55.5 MW), Krupa (50 MW), Banja Luka (40 MW), and Dabar (160 MW). In this regard, several neighboring countries and UCTE (Union for the Co-ordination of Transmission of Electricity) members have expressed interest in developing hydropower plants in B&H. Some of these plants may be financially and economically viable candidates for near-term capacity expansion if regional markets are realized. However, if the system operates in an isolated mode, new additions are not required until at least 2010.

Conclusions

This study shows that hydro plays an important role in the region and brings significant benefits to the regional electricity market. On the other hand, the operation of hydropower plants is affected by the regional market, with the LMPs becoming the driving factor for hydro operation.

Operating as a regional market, practically all of the countries in the region can expect lower energy supply costs, while some of the utility systems that are suffering occasional shortages of electricity supply would also have more reliable access to power through regional market purchases. In general, regional market operation allows for more cost-effective electricity production in the entire region by increasing the utilization of the most economical generating units, reducing the needs for certain ancillary services, lowering the risk of non-power water releases, and by increasing the overall reliability of system operation through better interconnections with other systems.

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