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Modeling the Real-Time Use of Reserves in the Joint Energy and Reserve Hourly Scheduling of a Pumped Storage Plant

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Outline

- Introduction
- Description of the main features of the model
- Methodology
- Case study and results
- Conclusions and future work

Introduction

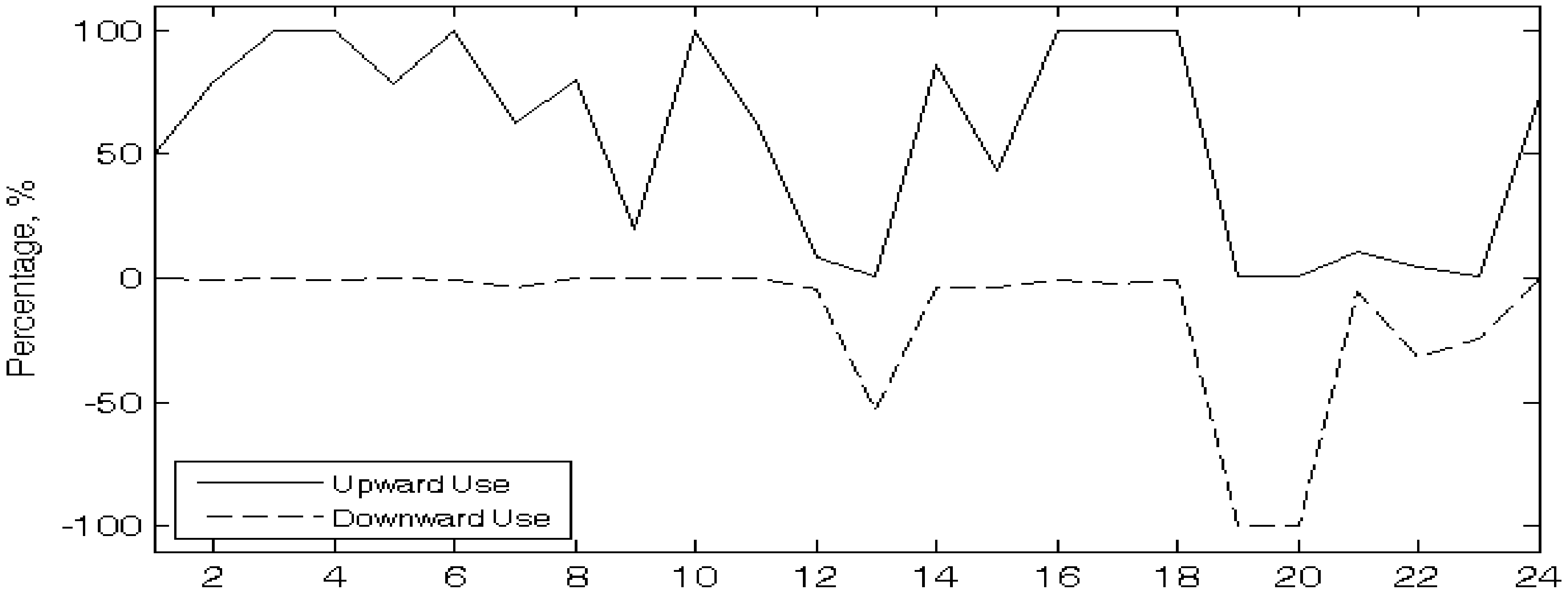
The secondary regulation service of the Spanish electricity system is composed by:

- A reserve market to allocate the expected requirements of the secondary regulation reserves of the system for the following day (power).
- A real-time use of the committed reserves (energy), carried out by the TSO.

In order to participate in this service, an agent must have been committed in the spot market previously.

Introduction (Cont.)

- Among all the uncertain parameters in the problem, this study focuses on the real-time use of the upward and downward reserves.
- This is an example of real data in 27/01/2013.
- Errors in forecasting the real-time use of reserves may have an impact in:
  - The income from the regulation energy.
  - The regulation energy and, hence, in the water volume trajectory.



Features of the Model

1. Time horizon of one day, discretised in hourly periods.
2. The hydrosystem is composed by an upper and lower reservoirs and several reversible Francis units, which pump water at fixed speed.
3. The pumped-storage plant is deemed as daily-cycle and closed-loop (without water inflows and outflows in the system).
4. The plant maximises the income participating in the Spanish system, in the spot and reserve markets, the income due to the activation of the reserves and the income due to the scheduled imbalances.
5. The following six parameters are assumed to be perfectly known when decisions are taken:
    i. Spot market price.
    ii. Secondary regulation reserve market price.
    iii. Upward secondary regulation energy price.
    iv. Downward secondary regulation energy price.
    v. Upward imbalance price.
    vi. Downward imbalance price.

Features of the Model (Cont.)

6. The following two parameters are supposed to be unknown when decisions are taken:
   i. The percentage of the real-time use of upward secondary regulation reserves.
   ii. The percentage of the real-time use of downward secondary regulation reserves.
7. The target water volume at the end of the day is input data.
8. Head dependency is not included in the model because we assume that the upper reservoir has a negligible head variation in comparison with the available gross head.
9. The pumped-storage producer is assumed to be price-taker in all markets. Further steps will consider price-maker approach in the reserve market.
10. Start-up costs are taken into account according to Nilsson(1997).
11. Secondary regulation energy is remunerated according to the "net energy", i.e. upward minus downward regulation energy.

Methodology

The problem is split in three parts and corresponds to a single day (27/01/2013):

1. The schedules in the spot and reserve markets, and the scheduled imbalances are obtained, considering perfect knowledge of all data of the Spanish electricity system and the following real-time use of reserves (RTURs) (five problems for the proposed day).

Approach	Upward RTURs	Downward RTURs
A	0% in all hours	0% in all hours
B	100% in all hours	100% in all hours
C	Hourly mean value in period 2012	Hourly mean value in period 2012
D	ARMA(12,8) model	ARMA(24,22) model
E	Perfect knowledge of the RTURs	Perfect knowledge of the RTURs

Methodology (Cont.)

2. After the deployment of the committed reserves, the energy and reserve schedules remains the same but the secondary regulation energy may change and, therefore, the water volume trajectory of the upper reservoir.

Part I: Optimal Schedule	→	Part II: Water Volume Deviations	→	Part III: Correcting Deviations
Results from the model		Simulation with the actual percentage of the RTURs		Simulation reneging on the committed schedules

3. Finally, if deviations occur, two main strategies can be followed:
   - Not to correct the deviations of the regulation energy and the water volume and start the following day at the deviated volume.
   - Correct the deviations and finish the day at the target water volume in order to follow the guidelines of a longer-term model.

Methodology (Cont.)

- Among all the corrective strategies, we have studied in this paper the strategy of reneging on the committed reserve schedule and on the secondary regulation energy.

- According to the rules of the Spanish electricity market:

    - The penalty associated to renege on the committed secondary regulation reserves is the reserve price in the respective hour and multiplied by a factor of 1.5, Section 10.2 of P.O. 7.2.

    - The penalty associated to renege on the secondary regulation energy is penalized by the upward or downward imbalance price, depending on the direction of the imbalance, Section 13.4.1 of P.O. 14.4.

Case Study

- The proposed pumped-storage plant is composed by a single unit with the following data.
- Power is expressed in MW, flow in m^3/s, start-up costs in € and water volume in Mm^3.

Turbine Mode

Max Power	Max Flow	Min Power	Min Flow	Start-up Cost
190.31	55.56	69.11	23.89	735.47

Upper Reservoir

Max Volume	Min Volume	Initial Volume	Final Volume
2	0	1	1

Pump Mode

Max Power	Max Flow	Start-up Cost
190.31	42.38	603.84

Results

- The cost of correcting the water volume deviations is obtained as the difference between the total income with and without deviations.
- The difference of the total income without deviations between each Approach and Approach E (VPQ) gives an idea of the value of perfect information of the real-time use of reserves plus the value of the quality of the proposed strategy to correct the water deviations.

Approach	Income with water Deviations (€)	Income without water Deviations (€)	Water Volume Deviations (Mm^3)	Cost of Correcting Deviations (€)	VPQ (€)
A	114352	15728	-0.272	98624	80166
B	96488	36827	-0.02	59660	59066
C	113598	19810	-0.26	93788	76084
D	116345	18879	-0.35	97466	77015
E	95894	95894	0	0	0

Conclusions

- The water volume deviations with respect to the target value may be significant, 17.5% of the maximum storage capacity in Approach D of this case study, and depend strongly on the forecast of the real-time use of reserves (between 17.5% in Approach D and 1% in Approach B, in the same day).

- The cost of correcting the water volume deviations in the water volume may be high. In this case study, the cost was between 61.83% in Approach B and 86.25% in Approach A, comparing to the total income without correcting the said deviations.

- The value of perfect information (VPI) of the real-time use of reserves and the value of the quality of the proposed corrective action (VQS) may be also significant. In this case study, they represent between 61.59% in Approach B and 83.59% in Approach A of the maximum theoretical income (Approach E).

Future Work

1. Obtain a more robust conclusion, enlarging the case study to a period of time of, for example, two years.
2. Analyse the impact of the errors of the real-time use of reserves when the pumped-storage plant is considered as a price-maker in the reserve market.
3. Analyse other strategies to correct deviations, for example, participating in intraday markets.
4. Compare the cost of correcting the water volume deviations following the proposed strategy, with the decrease in revenue obtained in the following day.
5. Analyse the impact of the errors of the real-time use of reserves in pumped-storage plants that can provide load-frequency control in pumping mode:
    i. Reversible Francis pump-turbines with the variable speed technology in pumping mode.
    ii. Pumped-storage plants operating in hydraulic short-circuit mode.

References

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Thank you!

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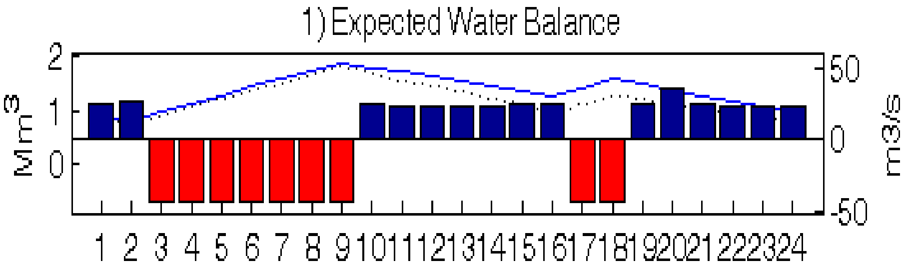
Results of the Approach C



Results of all Approaches

The economic results under the assumptions in each Approach after the deployment of the reserves…

Approach	Total	DM	SM	ER2UP	ER2DW	DESUP	DESDW	cSUPt	cSUPp	dVol
A	114352.5	35741.63	89358.33	20320.98	-1284.25	0	-26370.07	-2206.41	-1207.68	-0.27
B	96488.24	22997.54	85650.83	20320.98	-1284.26	0	-27782.76	-2206.41	-1207.68	-0.02
C	113598.5	35741.63	89358.34	20320.98	-1284.26	0	-27124.09	-2206.41	-1207.68	-0.26
D	116345.8	34772.69	88403.57	20220.37	-1284.26	0	-22352.48	-2206.41	-1207.68	-0.35
E	95894.33	24070.68	82207.73	16278.13	-1284.26	0	-21963.86	-2206.41	-1207.68	0

…and after correcting the water volume deviations with the proposed strategy:

Approach	Total	DM	SM	ER2UP	ER2DW	DESUP	DESDW	cSUPt	cSUPp
A	15728	35741.63	23856.73	1845.79	-15931.98	0	-26370.08	-2206.41	-1207.68
B	36827.85	22997.54	36064.56	18779.50	-9816.90	0	-27782.76	-2206.41	-1207.68
C	19810.11	35741.63	25958.35	3619.87	-14971.57	0	-27124.09	-2206.41	-1207.68
D	18879.07	34772.69	23990.38	6222.70	-20340.13	0	-22352.48	-2206.41	-1207.68
E	95894.33	24070.68	82207.73	16278.13	-1284.26	0	-21963.86	-2206.41	-1207.68