Book of Abstracts

NCR-Days 2013

Delft, October 3-4

Teaming up with nature and nations

NCR-PUBLICATION 37-2013

A. Crosato (ed.)

Adapting multireservoir operation to shifting patterns of water supply and demand: a case study for the Xin'anjiang-Fuchunjiang Reservoir Cascade

E. Vonk[1], Y. Xu[2], M.J. Booij[1], X. Zhang[2] and D.C.M. Augustijn[1]
[1] Dep. of Water Engineering and Management, University of Twente, P.O. Box 217, 7522 NB Enschede, The Netherlands
[2] Institute of Hydrology and Water Resources, Zhejiang University, Hangzhou 310058, China

Introduction

Climate change, rapid economic developments and further growth of the human population are regarded as the major drivers of increasing water-related problems worldwide. The developments pose a challenge to the management of water resources systems as these are designed to maintain a fragile balance between water supply and demand. With the projected changes, this balance is likely to be disrupted, ultimately requiring adaptation of existing infrastructure. In this study we investigated a possible adaptation strategy for multireservoir systems based on recent scientific advancements in interlinked simulation-optimization of water resources systems, which suggest that adjusting reservoir operation can significantly increase system performance (Rani and Moreira, 2010; Chang et al., 2010). Our objective was to determine whether dam reoperation (the adjustment of reservoir operating rules) is an effective adaptation strategy to reduce the potential impacts of climate change and regional socio-economic developments. The Xin'anjiang-Fuchunjiang reservoir cascade, located in Hangzhou Region (China), was selected as case study (Figure 1).

Figure 1. The upstream Xin'anjiang Reservoir.

Method

We used a scenario-based approach to explore the effects of various likely degrees of water stress for the future period between 2011 and 2040, which have been compared to the control period from 1971 to 2000. Water demand was estimated by considering three underlying socio-economic forces (rural and urban population growth, industrial production and changing land use). Climate change is considered as underlying process influencing the supply side. Projected streamflows for the future period were simulated using the GR4J rainfall-runoff model (Perrin et al., 2003). We obtained the input for the hydrological simulations by dynamic downscaling of global climate simulations. The HadRM3P Regional Climate Model was employed, driven by the HadCM3 Global Circulation Model. We evaluated the A2, A1B and B2 SRES greenhouse gas emission scenarios, resulting in, respectively, a small, medium and large decrease of inflow to the study area. The different inflow projections were combined with low, moderate and high socio-economic growth projections for water demand, resulting in a total of five water stress scenarios: Low (L), Moderate 1 (M1), Average (A), Moderate 2 (M2) and High (H).

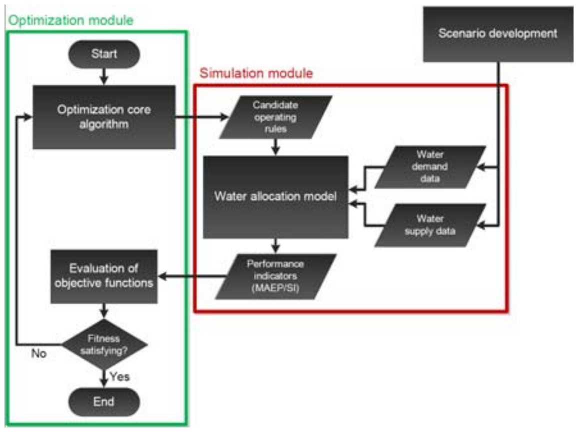

Figure 2. Modelling flowchart.

The scenario impacts were simulated with the WEAP water allocation model (SEI, 2013), which has been interlinked with the NSGA-II multiobjective metaheuristic algorithm in order to derive optimal operating rules adapted to each scenario (Figure 2). Target parameters for optimization were the coefficients of proposed linear hydropower production rules for each of the two reservoirs in the cascade, discriminating between four seasons (in total 24 target parameters). Reservoir performance was optimized for the Shortage Index (SI) and Mean Annual Energy Production (MAEP).

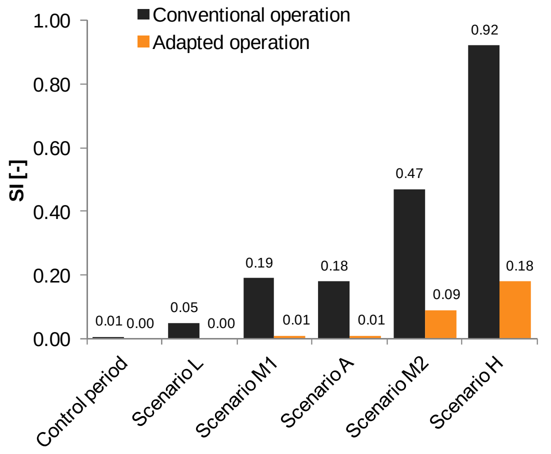

Figure 3. Performance of conventional and adapted operation in terms of water shortages.

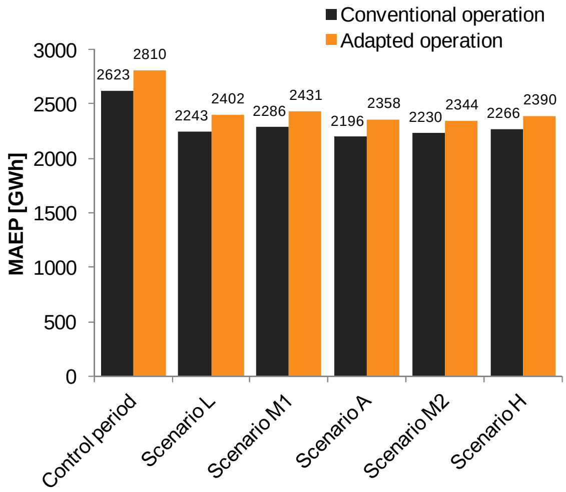

Figure 4. Performance of conventional and adapted operation in terms of hydropower production.

Results

As a reference for our analysis, we first simulated the performance of conventional reservoir operating rules for both the control period and future scenarios. We found a SI of 0.01 for the control period and values ranging from 0.05 to 0.92 for the investigated future scenarios (Figure 3). Even though the increasing SI implies that more drought problems are likely in the future, the deficits are still moderate compared to what is generally regarded as acceptable (Gosschalk, 2002; Chou et al., 2013). Compared to the control period, the MAEP is projected to decrease with 12.8% to 16.3% in the future scenarios (Figure 4).

Optimization resulted in a well-distributed Pareto front of solutions for each of the five future scenarios. We compared the optimization results with the performance of conventional operation by selecting the midpoints of each obtained Pareto front. Performance differences between conventional and adapted operation are shown in Figures 3 and 4. For the investigated scenarios, adapted operating rules on average reduce the SI with 84% and increase the MAEP with 6.4% (compared to the projected future performance of conventional operation).

Conclusions

We conclude that for the investigated reservoir system, dam reoperation is an effective adaptation strategy, significantly reducing the impact of changing patterns of water supply and demand. Yet it should be noted that it is insufficient to completely restore system performance to that of the control period. The improvements show that the chosen interlinked simulation-optimization approach is a promising technique to derive multireservoir operating rules that are adapted to projected changes in climate or water demand. Even though we have investigated the specific case of Hangzhou Region, this methodology can directly be applied to any other water resources system.

References

Chang L., Chang F., Wang K. and Dai S. (2010), Constrained genetic algorithms for optimizing multi-use reservoir operation. Journal of Hydrology, 390: 66-74.

Chou F., Lee H. and Yeh W. (2013), Effectiveness and Efficiency of Scheduling Regional Water Resources Projects. Water Resources Management, 27:665–693.

Gosschalk E. (2002), Reservoir Engineering: Guidelines for Practice. Thomas Telford, London.

Perrin C., Michel C. and Andréassian V. (2003), Improvement of a parsimonious model for streamflow simulation. Journal of Hydrology, 279:275-289.

Rani D. and Moreira M. (2010), Simulation-Optimization Modeling: A Survey and Potential Application in Reservoir Systems Operation. Water Resources Management, 24:1107–1138.

SEI (2013), WEAP: Water Evaluation And Planning system. http://www.seiinternational.org/weap-the-water- evaluation-and-planning-system. Accessed 26 April 2013.