TIP 258: Development of a State-of-the-Art Computational Framework and Platform for the Optimal Control of Multi-reservoir Systems under Uncertainty

Context

Much of the power produced by the Federal Columbia River Power System (FCRPS) is incidental to the water management activities required for multiple non-power uses and other system objectives. A single objective function is not adequate to describe the goals of operating the FCRPS under these conditions. Further, it is a common occurrence that there is a significant difference between forecasted and actual streamflows. Most models lack state-of-the-art strategies matching flexibility (global and local), uncertainty, and optimization of multiple objectives with visualization and high-performance computing.

The computational burden of hydraulic routing models constitutes a severe limitation, even without considering uncertainty, because the implementation of a real-time operation strategy combining simulation and optimization may require hundreds or even thousands of simulations for each operational decision. Thus, a faster, more flexible, user-friendly system is imperative to better model and control of this increasingly complex river system.

Description

This project's state-of-the-art model can (1) handle uncertainty and risk analysis, (2) quantify operational flexibility, and (3) visualize and display large amounts of complex data to support real-time and planning decisions,

The result of this two year research project is a hybrid optimization computer model that is a tool for the real-time operation and planning of a multi-objective, multi-reservoir systems accounting for uncertainty and flexibility. The computer model produces stable and feasible results in high-resolution time steps and can account for uncertainty as well as global and local flexibility.

Furthermore, the platform used for the model development is MATLAB, which is under continuous development. It integrates computation, visualization, and programming in an easy-to-use environment. That makes this environment a suitable platform for easy integration with any current or future framework used by BPA, including power production and marketing.

Benefits

The primary contribution of the research is the development of a novel framework for modeling uncertainty in complex systems, which can be exploited for efficient and robust, multi-objective optimization.

The resulting model could potentially replace or be integrated with the current tool used by BPA for short-term operation planning of the FCRPS.

Accomplishments

The overall goal of the research was to produce a robust and computationally efficient hybrid and parallelized framework for the real-time operation of multi-objective and multi-reservoir systems that accounts for uncertainty and flexibility.

Project objectives achieved included:

1. *Robust and efficient multi-objective optimization:* Assemble in MATLAB a model that is a robust and computationally efficient hybrid optimization. Computational efficiency is achieved by using spectral analysis to guide variable reduction. Optimal solutions are then achieved by combining a genetic algorithm with local search methods.
2. *Uncertainty:* Develop an innovative uncertainty modeling and propagation framework.
3. *Flexibility:* Develop a flexibility framework and implementation into the multi-objective optimization model.
4. *Visualization:* Assemble a state-of--the art and operator preferred visualization in MATLAB.
5. *Integrate the developed model components:* The resulting tool is a hybrid model for the real-time operation and planning of multi-objective and multi-reservoir systems accounting for uncertainty and flexibility.

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Project Start Date: October 1, 2012

Project End Date: December 31, 2015

Deliverables

Compiled Computer Model and User's Manual:

A fully functional compiled model along with a user's manual is provided. The platform for the model is in MATLAB.

Final Report: The final report contains a description of pilot tests done for stability, accuracy, uncertainty and flexibility performance, and CPU time compared to other algorithms. This comparison clearly shows the benefits of each component of the computer model with respect to other to available algorithms in the literature.

The final report also describes the research in detail, its benefits and the next steps for potential follow-on projects.

Conclusions

Overall the data acquisition, processing, and hydraulic simulation test case was successful. The methods of acquiring and processing the available data are feasible, but would require additional support in order to apply the process to the full extent of the Columbia River system. If the requested HEC-RAS data is received, all necessary geometry data for the hydraulic simulations would be available to our research group.

Participating Organizations

Oregon State University

Funding

Total Project Cost: $1,157,000

For More Information Contact:

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Related Projects

TIP 259: Short-Term Hydropower Production and Marketing Optimization (HyProM)

TIP 265: Computationally Efficient, Flexible, Short-Term Hydropower Optimization and Uncertainty Analysis (SHOA) for the BPA System

TIP 342: Framework for Quantification of Risk and Valuation of Flexibility in the FCRPS