Power Generation Simulation of a Hydropower Reservoir System Using System Dynamics: Case Study of Karoon Reservoir System

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Abstract: The system dynamics approach is an object-oriented simulation method based on feedback loops, flow diagrams, and flow and state variables, which can be used in the development of a water system's operational policies and water-resource management. In reservoir operation simulations, there are iterative procedures (feedback loops) due to the dependency of reservoir release on both initial and final reservoir storage. System dynamics can successfully satisfy this need. Given the complex implicit and nonlinear relationships that exist in hydropower reservoirs, the system dynamics approach can be efficient in the planning and management of those reservoirs. This paper develops a system-dynamics simulation model using Vensim for the operation of a hydropower reservoir system (Khersan 1, Karoon 4, and Karoon 3) that is located in series and in parallel in the Karoon river basin, Iran. Steps of the model design include definition of decision variables, formulation of model, and method of solution to compute the output of the hydropower reservoirs. To assess the effects of the reservoirs on each other and the importance of each reservoir, operational scenarios are considered. Reservoir performance criteria (reliability, resiliency, and vulnerability) and mean energy production over a 44-year simulation period are calculated for each operational scenario. The results show that addition of the Khersan 1 reservoir to the system composed of Karoon 4 and Karoon 3 reservoirs increases the average amount of energy production by 20% without a significant loss in performance criteria. The sensitivity analysis for Khersan 1 is conducted in two states. The amounts of installed capacity of the power plant and maximum storage volume of the reservoir are increased by 20% and decreased by 20%, respectively. The results show that, in terms of energy production, the effect of increasing the installed power-plant capacity of Khersan 1 is greater than that of increasing the maximum reservoir storage volume of this reservoir. Therefore, by considering the same percentage increase (20%) in both installed capacity and maximum storage volume, it is preferable to increase the installed capacity of the power plant at Khersan 1 reservoir. **DOI: 10.1061/(ASCE)EY.1943-7897.0000179.**

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Introduction

Limited water resources and increased demand for the resources necessitate comprehensive, integrated, best-management plans (Bozorg Haddad et al. 2008a; Seifollahi-Aghmiuni et al. 2011; Sabbaghpour et al. 2012). Efficient procedures are needed for the allocation of water and operation of water systems that focus on increasing the efficiency of water consumption and allocation management (Moradi-Jalal et al. 2007; Bozorg Haddad et al. 2009; Noory et al. 2012). Many simulation and optimization techniques and procedures have been developed recently to facilitate the general evaluation of water-resource problems (Bozorg Haddad et al. 2011a; Rasoulzadeh-Gharibdousti et al. 2011; Bozorg Haddad and Mariño 2011; Karimi-Hosseini et al. 2011; Fallah-Mehdipour et al. 2011a, b) and the particular problems in reservoir operation (Bozorg Haddad et al. 2008b, 2011b). The system-dynamics approach is a procedure that facilitates the evaluation of engineering and management problems.

Planning and analysis of reservoir systems play important roles in the integrated management of the water resource. In this context, simulation is an important tool in reservoir management. Simulation tools can be used to describe complex systems and compare different operational policies. Moreover, users can easily extend a simulation model by adding knowledge acquired in previous operations.

System dynamics (SD) is a modeling and simulation approach that uses feedback loops, flow diagrams, and flow and state variables whose values change over time. In this approach, variables influence other variables, either individually or in combination, and cannot be investigated separately. Casual cycles and the effect of different variables must be specified clearly in this approach. System dynamics procedures can be used to monitor performance indicators and increase the efficiency in managing water effectively and sustainably.

Shelley et al. (2001) developed and tested a system-dynamics model to study significant processes and appropriate levels of detail required to capture dynamic behavior that is important in managing biodegradation in landfills. This problem is related to problems inherent in a water-resource management system. The simulation results suggested that inhibition of hydrogen in fermentation is

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