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Multi-reservoir real-time operation rules: a new GP approach

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This paper employs non-linear programming (NLP), genetic algorithms (GAs) and fixed-length gene genetic programming (FLGGP) for the real-time operation of a three-reservoir system (Karoon4, Khersan1 and Karoon3) in which dependent and independent approaches are used to forecast the hydroelectric energy generated by the system. A total deficiency function as well as efficiency criteria are used to investigate the results obtained. The latter indicate that the more flexible FLGGP gives the most efficient function for the extraction of reservoir operation rules in both dependent and independent approaches. By comparing the two approaches, no significant difference was observed. Consequently, due to the simplicity of the application of the forecast-independent approach, it is suggested for application in the extraction of reservoir operation decision rules. Moreover, the advantages of a three-reservoir system operation over a single-reservoir system operation reflect the efficiency of the integrated management of water resource systems.

1. Introduction

There are more than 500 000 large dams in the world (Cabecinha *et al.*, 2009). Covering multiple economic, social and cultural purposes, optimal usage of these dams/reservoirs is crucial in water planning and management (Fallah-Mehdipour *et al.*, 2011a). In their planning for the utilisation of dams/reservoirs, operators thus need effective operation policies (Bozorg Haddad *et al.*, 2009), which involve determination of an appropriate water release rate from a dam during the period of operation under various conditions, aiming to meet the main objectives of the dam (Noori *et al.*, 2012).

Investigators are consistently seeking to introduce methods with high efficiency to elicit operation policies and rehabilitation strategies (Bozorg Haddad *et al.*, 2008a; Fallah-Mehdipour *et al.*, 2011b; Sabbaghpour *et al.*, 2012). Non-linear programming (NLP) and genetic algorithms (GAs) are two common methods used in reservoir operation and are widely employed in water engineering (Moradi-Jalal *et al.*, 2007; Rasoulzadeh-Gharibdousti *et al.*, 2011).

Simonovic and Mariño (1982) employed a reliability programming model to manage a system of multi-purpose reservoirs. The reliability programming model is non-linear and can be split into two models – a search model and a special linear programming model. Results of the operation of the system, including optimal operating policies for the reservoirs and reliabilities of the operation, illustrate the major advantages of the reliability programming approach compared with other stochastic optimisation techniques. Mariño and Loaiciga (1985a, 1985b) developed dynamic and quadratic models for planning the operation of multi-purpose reservoir systems in California. The optimal release policies showed a potential increase in the system total annual energy with respect to heuristic schedules that were in use. Raman and Chandramouli (1996) derived reservoir operating policies by employing a dynamic programming (DP) model, a stochastic dynamic programming (SDP) model and a standard operating policy (SOP). From the DP algorithm, general operation policies were extracted using a neural network procedure (DPN model) and a multiple linear regression procedure (DPR