A BAYESIAN SDP MODEL FOR MULTI-RESERVOIR OPERATION

NIRMALA, B [1] and MUJUMDAR, P.P [2]

[1] Research Scholar, Department of Civil Engineering,
Indian Institute of Science, Bangalore,
(e-mail: nirmalab@civil.iisc.ernet.in)
[2] Professor, Department of Civil Engineering,
Indian Institute of Science, Bangalore, 560 012
(Tel: +91-080-22932669, Fax: +91-80-2360 0290, e-mail: pradeep@civil.iisc.ernet.in)

In this paper, an operating policy model is developed for a multi-reservoir system for hydropower generation by addressing forecast uncertainty along with inflow uncertainty. The stochastic optimization tool adopted is the Bayesian Stochastic Dynamic Programming (BSDP). The BSDP model proposed by Karamouz and Vasiliadis, [1992] is essentially a dynamic programming model, which incorporates a Bayesian approach within the classical Stochastic Dynamic Programming (SDP) formulation [Loucks et al., 1981]. The BSDP model developed in this study considers, the storages of individual reservoirs at the beginning of period t, aggregate inflow to the system during period t and forecast for aggregate inflow to the system for the next time period t+1, as state variables. In order to reduce the complexity of the model and to make the solution computationally tractable, aggregate inflow is taken as a state variable, rather than accounting for one state variable each corresponding to the inflow to an individual reservoir. Likewise, forecast for aggregate inflow is taken as the state variable, rather than forecasts of inflow to individual reservoirs. The randomness of the inflow is addressed through a posterior flow transition probability, P^{t}_{imj}, and the uncertainty in flow forecasts is addressed through both the posterior flow transition probability, P^{t}_{imj}, and the predictive probability of forecasts, P^{t+1}_{jn}. The posterior flow transition probability, P^{t}_{imj}, gives the probability that the flow Q_{t+1} in time period t+1 belongs to the class interval j, given that the flow Q_t in time period t belongs to class interval i and the forecast H_{t+1} for flow in time period t+1, belongs to class interval m. The predictive probability of forecasts, P^{t+1}_{jn}, gives the probability that the forecast H_{t+2} for flow in time period t+2 belongs to class interval n, given that the flow Q_{t+1} in previous period t+1 belongs to class interval j. The time horizon for which decisions need to be obtained is taken as one year, with months taken as stages in the dynamic programming algorithm. Since the storage transformation at a reservoir requires the inflow to that reservoir, the aggregate inflow to the system during period t, Q_t, is spatially disaggregated to inflows to individual reservoirs. The system performance measure used in the BSDP model is the square of the deviation of the power generated from the firm power and is obtained from a hydropower generation model. The hydropower generation model computes the power generated, using the net head corresponding to the average value of beginning-of-period and end-of-period storages of the reservoir, and the release to penstocks from the reservoir. The objective function of the

BSDP model is to minimize the expected value of the system performance measure, for a long-term operation of the reservoir system.

The model application is demonstrated through a case study of a two reservoir system. As a sufficiently long inflow record is not available, statistical rainfall-runoff model is used for computing the inflow to the catchment. The inflow forecasts for monsoon and non-monsoon periods are computed separately. Inflow forecasts for monsoon months are obtained from the rainfall-runoff model with the rainfall forecasts resulting from an Artificial Neural Network (ANN) model as input. For non-monsoon months, the aggregate inflow forecast is modeled using a non-stationary first order Markov model. The BSDP model solution results in the optimal steady state operating policy to minimize the expected value of the squared deviation of amount of hydropower generated from the firm power. The implication of the optimal operating policy derived from the BSDP model, is studied through simulation with four performance indicators, viz., Reliability, Resiliency, Vulnerability and Deficit ratio. Simulations are carried out with the BSDP policy for the power commitment of 270 MW using three different forecasts, viz., inflow forecasts resulting from an ANN rainfall forecast, forecasts as mean values of monthly inflows, and perfect forecasts of inflows i.e., forecasts equal to historical inflows. From these simulations, it is observed that the operating policies derived with the BSDP model are fairly insensitive to the accuracy of forecasts as the values of system performance indicators are almost the same for simulated operations with forecasts obtained from different models. This implies that the steady state policy derived with a BSDP model may be used in situations where the forecasting skills are small due to impacts of climatic variability or due to lack of adequate data (such as in the case of ungauged or poorly gauged basins).

REFERENCES

Karamouz, M., Vasiliadis. H. V. (1992), "Bayesian Stochastic Optimisation of Reservoir Operation Using Uncertain Forecasts", *Water Resources Research*, 28(5), 1221- 1232.

Loucks, D. P., Stedinger, J. R. and Haith, D. H. (1981), *Water Resources Systems Planning and Analysis*, Printice Hall, Eaglewood Cliffs, New Jersey, USA.