Optimal Operation of Klang Gate Dam Using Genetic Algorithm

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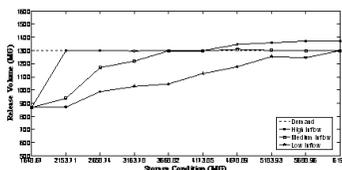
Abstract

Operation of a reservoir system is full of complexities as it deals with different uncertainties, nonlinearities and time dependent variables. An optimal water distribution relation needs to be maintained between water release and storage in every operational time period. In this study, water release curves have produced for every month of the year in respect of different initial storage conditions, so that it will be easier for the decision maker to understand the operating criteria. Most popular optimization technique- Genetic Algorithm (GA) has used to find out the optimal release with maintaining all the general constraints (such as- water balance, release bounds and storage constraints) of a reservoir system. Historical daily rainfall and storage data regarding Klang gate dam (located in Malaysia) has used as inputs of the model. Three different category of inflow (high, medium and low) has considered in search of the optimum solutions. 22 years of actual historical inflow data has used for model verification purposes. The results from the model and the patterns of the release curves shows that, GA can be used as a useful and easily applicable tool to developed the release policy for optimal operation of Klang gate dam.

Keywords: Reservoir operation; optimization; genetic algorithm; water demand/release analysis; releas policy

■1.0 INTRODUCTION

Every reservoir system needs to follow an operational guideline. Release policy for a reservoir is such a guideline for the decision maker. An optimal release policy can provide the best outcomes, which always expected from a reservoir system. Though the researchers now these days has made exceptional improvement in the field of optimal reservoir operation system, more efficiency needed for expanding water demands. The water demands included for municipal uses, irrigation, hydro-power production, flood control, recreations, ecological requirements, etc. The linear programming (LP) (Crawley and Dandy 1993), dynamic programming (DP) (Yakowitz 1982), stochastic dynamic programming (SDP) (Braga *et al*. 1991) are the most common and popular optimization techniques has successfully used in this research field. GA is another modern technique and the application of GA increasing extensively day by day in every section (like engineering, economics, medical etc.) including in reservoir release optimization.

In this study a monthly release policy has developed by using real coded GA. 10 discrete values have taken between the storage capacity ranges to address the reservoir condition and release relations. Also the release policy has categorized by different inflow conditions.

■2.0 KLANG GATE DAM (KGD)

KGD is located in Taman Melawati, Malaysia. The major contribution of the KGD is supplying water for domestic uses to the people of surrounding areas. The dam height is 37 m with the total capacity of 6194 MG of water. The inflow pattern to the reservoir can be categorized into three sections for every month as given in Table 1. The targeted monthly demands also presented in Table 1. The operation rules for the KGD should follow the storage and release bounds of the reservoir. The storage bound for KGD operating policy has taken for all time period as 1648.67 MG – 6194 MG. Releases for any time period has kept in the range of 868 – 1379.50 MG. The storage bounds act as a constraint of this optimization problem.

■3.0 GENETIC ALGORITHMA (GA)

The main concept of GA firstly observed by Holland (1975) and got more popularity by the work of Goldberge (1989). After that many researchers (Srinivas and Deb 1995; Fonseca and Fleming 1995; Chang and Chen 1998; Wardlaw and Sharif 1999; Chang and Chang 2001; Deb *et al*. 2002) has contributed a lot to solve next generation single or multi objective optimization problems in the research field associated with GA. Encoding of objective variables is the first step in GA procedures. In reservoir

operation problem, normally releases are taken as the decision variables. A set of encoded variables is called population.

Table 1 Monthly inflow and water demand[a] (in MG) for KGD

Months	Inflow			Demand
	High	**Medium**	**Low**	
Jan	1506.89	760.85	123.12	1298.64
Feb	1901.08	1024.49	259.34	1083.09
Mar	2831.7	1646.31	923.24	1152.45
Apr	2919.74	1959.92	764.88	1173
May	2974.2	1786.87	938.31	1198.73
Jun	2825.69	1355.22	447.97	1271.73
Jul	2717.32	1618.95	645.61	1258.14
Aug	2948.26	1644.53	816.78	1206.41
Sep	3368.12	1859.86	631.15	1160.05
Oct	3545.83	2316.13	654.35	1204.14
Nov	3838.47	2342.89	1021.79	1213.09
Dec	2699.3	1455.7	340.69	1290.59

[a]Source: Puncak Niaga (M) Sdn. Bhd., Malaysia

Each random value of the variables represents a chromosome and different combination of these chromosomes made up different strings. The main objective of the study is to search a release policy during all time period (starting from January to December) that can provide the minimum water deficit with maintaining allowable storage conditions. In this study a set of 12 consecutive months (Jan-Dec) release values considered as a string. A defined number of strings (generally called population size) made up the population.

The algorithm begins with an initial population consist randomly generated possible solutions. Three main operator of GA – selection, cross-over and mutation handle this population and update it by eliminating weaker solution. For selection purpose different selecting rule can be applied (Goldberg and Deb 1991). After selecting the strings that contained better solution, cross-over and mutation takes place in the algorithm. Here we used a modified cross-over techniques described in the study of Haupt and Haupt (2004).

The priority of being selected as a good solution is solely depends on their fitness values (objective function values) of the corresponding solutions. After certain iteration the algorithm reach to the optimal solution. In handling the constraints of reservoir release optimization problems, penalty function method is reliable and suitable option (Wardlaw and Sharif 1999). In penalty function method, a penalty term is added upon the violation of any constraint.

■4.0 MODEL FORMULATION

Minimizing water deficit has considered as the main objective function of the problem and given as equation 1.

$$\min f(x) = \sum_{t=1}^{12} \left(D_t - x_t \right)^2 \qquad (1)$$

In equation (1), x_t refers release and D_t denotes demand for a time period $t=1, 2,\ldots\ldots, 12$. The storage condition (S) for a month, related with a certain release calculated by using mass balance equation (equation – 2).

$$S_{(t+1)} = S_t + \text{Inflow}_t - \text{Release}_t - \text{Losses}_t \qquad (2)$$

In this study we eliminated the release options, those leads to violate the storage constraints. For this purpose two penalty terms are introduced to equation (1). The penalty terms are given as –

$$penalty1 = \begin{cases} 0 & \text{if } S_t > S_{min} \\ C_1(S_{min} - S_t)^2 & \text{if } S_t < S_{min} \end{cases} \quad \text{and}$$

$$penalty2 = \begin{cases} 0 & \text{if } S_t < S_{max} \\ C_2(S_t - S_{max})^2 & \text{if } S_t > S_{max} \end{cases}$$

Here C_1 and C_2 are the large numerical values and normally known as penalty co-efficient. The value of these coefficients are totally problem dependent.

■5.0 RESULTS AND DISCUSSIONS

Monthly release policy has been developed for three inflow category with the provided results by GA optimization model. Such release policies for the January month has shown in Figure 1. With this guideline a decision maker can make the decision on releasing water by observing the inflow amount and current reservoir level.
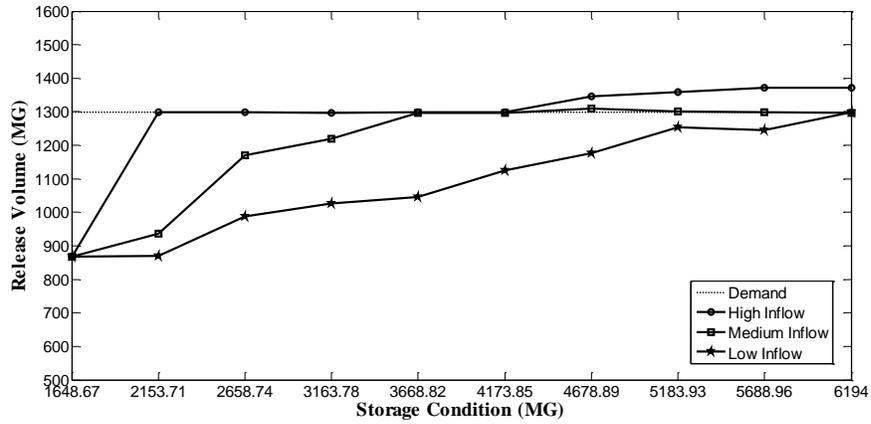
Figure 1 Release curves for the month of January

The objective function values through 1000 iterations of the GA model have shown in Figure 2 (for medium inflow and medium storage condition). The string consist optimum release options among a population, should poses the minimum fitness value of any iteration.

For high inflow category, release curves meet the demand line very early but with increasing storage capacity it suggest to release more than demand to keep the storage level in safe ranges. Also for the lower inflow situation it's very difficult to supply according to exact demand and the shortage is very

obvious in this situation. Here the release curves for high, medium and low inflow (in Figure 1) reflecting the same exact criteria of releasing water.

A simulation has done by using 22 years (Jan 1887 – Dec 2008) of historical inflow data. From the release curve of every month we computed the optimum release and observed model performances. For graphical convenience we presents only 14 years simulation results in Figure 3.

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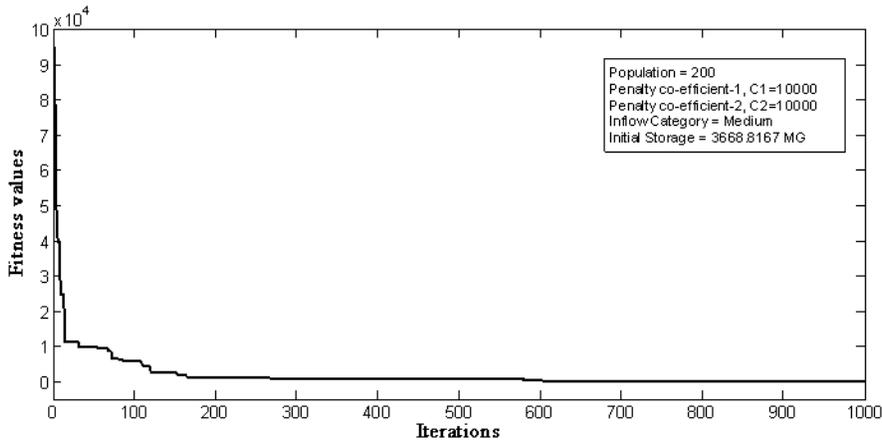
Figure 2 Fitness values through all iterations
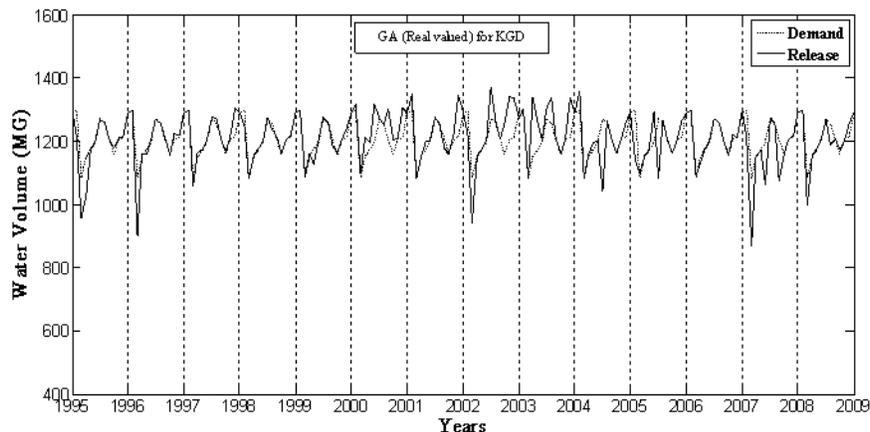
Figure 3 Release and demand analysis using historical inflow

Figure 3 shows the demands and the releases (obtained from GA release curves) for the historical years. From the simulation we observed that, out of total 264 months GA release policy able to meet the demand in 185 months. Also the shortage occurred only for very low inflow value.

■**6.0 CONCLUSIONS**

A reservoir release policy has developed n this study in a view of applying it for practical real world problem. Using GA optimization technique monthly release curves has produced.

From the release curves the decision maker can decide the amount of water to be released for a month after observing the inflow condition and reservoir level. From the simulation results we can see that GA can be used efficiently in search of reservoir operation policy.

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