Application of Genetic Algorithm for Optimal Reservoir Releases

Sumitra Sonaliya[1] Dr. T.M.V. Suryanarayana[2]
[1] PG Student [2]Associate Professor
[1, 2] Water Resources Engineering and Management Institute, Faculty of Tech. & Engg., the Maharaja Sayajirao University of Baroda, Samiala-391410, Vadodara, Gujarat, India

***Abstract*—**In the present study Genetic Algorithm (GA) has been used to develop a policy for optimizing the release of water for the purpose of irrigation. The study area is Ukai Reservoir project in Gujarat, India. Genetic algorithm technique is an optimization approach based on the mechanics of natural selection, derived from the Darwin's theory of natural evolution. The fitness function used is to minimize the squared difference between the monthly reservoir release and irrigation demand along with squared deviation in mass balance equation. The months considered in the study are July, August, September and October for the year 2010 and 2011 respectively. The results obtained using GA shows that the downstream demands for the purpose of irrigation are completely satisfied and also considerable amount of water is saved.

Key Words:- Optimization, Genetic Algorithm, Ukai Reservoir Project

I. INTRODUCTION

To obtain optimal operating rules, a large number of optimization and simulation models have been developed and applied over past few years. Evolutionary algorithms are stochastic search algorithms which have a lot of applications in water resources management. Genetic algorithm is a robust search and optimization technique for solving complex problems.

Genetic algorithm which is based on Darwin's principle of evolution was first proposed by Holland [1]. Fahmy et al.[2] applied GA for optimization of a reservoir system. They compared the results of this model with dynamic programming model and showed that GA has a high potential for optimization of large water resources systems. Morshed and Kaluarachchi [3] employed three GA enhancement methods to a nonlinear groundwater problem for minimizing the costs of pumping for meeting a specific demand. Reed et al. [4] presented a review of the existing tools from literature to ensure that a GA converges to an optimal or near-optimal solution. Labadie [5] in state of art review on optimal operation of multi-reservoir system highlighted different optimization models suitable for high-dimensional, dynamic, nonlinear and stochastic characteristic of reservoir system. In spite of extensive research in reservoir optimization, researchers are still in search of new optimizing techniques, which can derive more efficient reservoir operating policy for reservoir operation. GA is one such optimizing technique which it is robust and is considered in this study for deriving multipurpose reservoir operating policies. Raju and Nagesh Kumar[6] applied GA for evolving an optimum cropping pattern utilizing surface water resources in the command area of a multi-purpose reservoir system. Kim et al. [7] developed a monthly operating rule for single-reservoir operation. The piecewise- linear operating rule for the Soyanggang reservoir was developed using a multi-objective genetic algorithm (NSGA-II) and the synthetic inflow that was generated by time-series modeling. Mathur and Nikam [8] optimized the operation of an existing multipurpose reservoir in India using GA, and derived reservoir operating rules for optimal reservoir operations. Sonaliya and Suryanarayana [9] developed an optimal policy for a reservoir using genetic algorithm which showed that actual releases were minimized and a considerable amount of water was saved.

In the present study, a GA model has been used for optimizing the reservoir operating policy for the month of July, August, September and October for the year 2010 and 2011. The objective of this study is to minimize the squared difference between the monthly reservoir release and irrigation demand along with squared deviation in mass balance equation. The decision variables used are the release for irrigation demand, from the reservoir and initial storage in each month. The constraints used for this optimization are bounds for the releases and reservoir capacity.

II. STUDY AREA

The area selected for the present study is the catchment area of the Ukai dam, which is located across Tapi River near Ukai village of Fort Songadh taluka in Surat district. Its catchment is located between longitudes 73º32'25" to 78º36'3" E and latitudes 20º5'0" to 22º52'30" N. The dam is located at about 29 km upstream of the Kakrapar weir. The total catchment area of the Ukai reservoir is 62,225 sq. km, which lies in the Deccan plateau. The catchment of the dam covers large areas of 12 districts of Maharashtra, Madhya Pradesh and Gujarat. The districts that lie in the catchment include Betul, Hoshangabad, Khandwa, and Khargaon of Madhya Pradesh; Akola, Amravati Buldhana, Dhule, Jalgaon and Nasik of Maharashtra and Bharuch and Surat of Gujarat state. The command area of 66,168 Ha is spread over the districts of Surat, Tapi, Navsari and Valsad.

III. METHODOLOGY

Genetic algorithm is a method that is used for solving both constrained and unconstrained optimization problems based on natural selection, a process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, genetic algorithm selects individuals at random from current population to be parents and uses them to produce the children of next generation. Over successive generations, the population "evolves" towards an optimal solution. Genetic algorithm can be applied to a variety of of optimization problems which are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, non-differentiable, stochastic, or highly nonlinear. The genetic algorithm uses three main types of rules at each step to create the next generation from the current population:

- Selection rules select the individuals, called parents that contribute to the population as the next generation.
- Crossover rules combine two parents to form children for next generation.
- Mutation rules apply random changes to individual parents to form children.

The difference between Genetic algorithms and the traditional optimization methods:

- GAs work with coding of the parameter set but not with the parameters themselves.
- GAs search from a population of points, not a single point.
- GAs use objective function information, not derivatives or other auxiliary knowledge.
- GAs use probabilistic transitions rules, not deterministic rules.

Survival of fittest is applied to the strings based on Roulette Wheel Method. These strings are operated with reproduction, crossover and mutation. These will produce new values of decision variables and again the fitness is determined. The procedure is continued till the monthly release obtained is more than or equal to the monthly demand with minimum irrigation deficit. The accurate selection of the parameters affects the function and running speed of GA. So in the study different parameter were chosen that are Population size from 5 to 20, probability of crossover of 0.80, number of generations from 5 to 50. The data used for the development of the model are Actual releases (MCM), Demand (MCM), Storage(MCM), Inflow(MCM), Evaporation losses (MCM).

IV. Model Development

The reservoir can be operated to minimize the actual releases while satisfying the demands. In the present study, the fitness function used is to minimize the squared difference between the monthly reservoir release and irrigation demand along with squared deviation in mass balance equation. The months considered for the study are July, August, September and October for the year 2010 and 2011 respectively. The objective function is given by equation "(1.1)" and the constraints related to the objective function are given by equations "(1.2)" and "(1.3)".

$$\sum_{t=1}^{4} (Rt - Dt)^2 + \sum_{t=1}^{4} (St - S(t+1) + It - Rt - Et)^2 \quad \text{----- (1.1)}$$

Where,
R_t =Monthly irrigation release for the month 't'.
D_t = Monthly downstream irrigation demand for the month 't'.
S_t = Initial storage in the beginning of month 't'.
S_{t+1} = Final storage at the end of month 't'.
I_t = Monthly inflow during the period 't', and
E_t = Monthly evaporation loss from the reservoir during the month '*t*'.

The above fitness function of GA model is subjected to the following constraints and bounds,

A. Release Constraint.

The irrigation release during any month should be less than or equal to the irrigation demand in that month and this constraint is given by

$$R_t \geq D_t,\ t = 1, 2, 3, 4 \quad \text{----- (1.2)}$$

B. Storage Constraint.

The reservoir storage in any month should not be more than the capacity of the reservoir, and should not be less than the dead storage. Mathematically this constraint expressed as:

$$S_{min} \leq S_t$$

And

$$S_t \leq S_{max};\ t = 1, 2, 3, 4 \quad \text{----- (1.3)}$$

Where,
S_{min} = Dead Storage of the reservoir in MCM and
S_{max} = Maximum capacity of the reservoir in MCM.

V. Results And Discussion

Table I
Releases Obtained By Ga For The Year 2010

Year	2010		
Month	Actual Release MCM	GA Release MCM	Demand MCM
July	53.47	242.61	242.53
August	751.65	71.50	70.59
September	2240.52	852.72	850.30
October	343.27	91.05	90.70

Table I shows the values of Actual release, GA releases obtained by Genetic Algorithm and Demand for the months of July, August, September and October for the year 2010. In the months of July, August, September and October, the demand is completely satisfied with an excess of 0.08, 0.91, 2.42 and 0.35 MCM respectively.

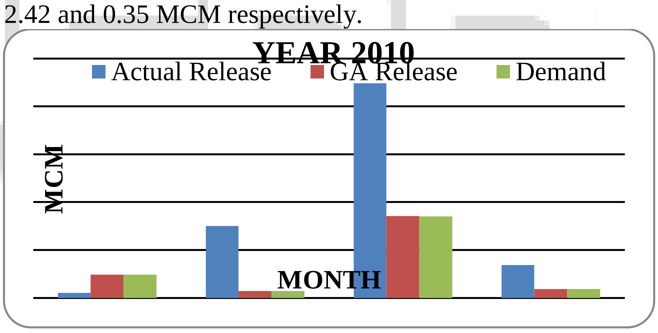

Fig. 1: Releases obtained by GA for the year 2010

Fig.1 shows the actual releases, releases obtained by GA and Demand for each of the month of July, August, September and October for the year 2010. From Fig.1, it can be shown that, in the month of July the release obtained by GA is more than the actual release but, care is taken to satisfy the demand and in the months of August, September and October, the actual releases are minimized upto a considerable amount. These releases obtained are considered optimal releases.

Table Ii
Releases Obtained By Ga For The Year 2011

Year	2011		
Month	Actual Release MCM	GA Release MCM	Demand MCM
July	151.93	335.69	335.69
August	1754.43	1405.25	1403.54
September	1770.86	1532.70	1530.89
October	353.00	201.28	200.70

Table II shows the values of Actual release, GA releases obtained by running the algorithm and Demand for the months of July, August, September and October for the year 2011. In the month of July, August, September and October the demand is completely satisfied with a no excess in July and an excess of 1.71, 1.81and 0.58 MCM respectively in the other months.

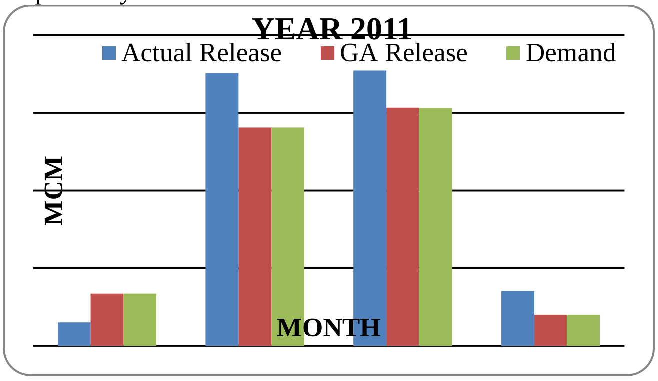

Fig. 2: Releases obtained by GA for the year 2011

Fig.2 shows the actual releases, releases obtained by GA and Demand for each of the month of July, August, September and October for the year 2011. From Fig.2, it can be shown that, in the month of July the release obtained by GA is more than the actual release but, care is taken to satisfy the demand and in the months of August, September and October, the actual releases are minimized up to a considerable amount. These releases obtained are considered optimal releases.

VI. CONCLUSIONS

An optimal policy has been developed for release of water from the Ukai reservoir project for the purpose of irrigation. The releases developed by Genetic algorithm satisfy completely the irrigation demands for all the four months, i.e. July, August, September and October for both the years 2010 and 2011. It is also observed that in almost six out of eight months, the optimal releases obtained by genetic algorithm, are less than the actual releases, which leads to considerable amount in saving of water.

REFERENCES

[1] Holland, J.H., “Adaptation in Natural and Artificial Systems.” MIT press, Cambridge, Mass, 1975.
[2] Fahmy, H.S., J.P. King, M.W. Wentzel and J.A. Seton, “Economic optimization of river management using genetic algorithms”, Summer meeting, American Social of Agriculture Engineers, St. Joseoh, Michael Paper No. 943034, ASCE, International, 1994.
[3] Morshed, J., and Kaluarachchi, J., “Enhancements to genetic algorithm for optimal ground-water management.” J. HydrologicEng., 5(1), 67–73, 2000.
[4] Reed, P., Minsker, B., and Goldberg, D. E. _2000_. “Designing a competent simple genetic algorithm for search and optimization.” Water Resour. Res., 36(12), 3757–3761, 2000.
[5] Labadie John W., “Optimal operation of multireservoir systems: state-of-the- art review", Journal of water resources planning and management, pp 93-110, March/April 2004.
[6] Raju, K. and S.D. Nagesh Kumar, “Irrigation planning using genetic algorithms.” Water Resour. Manage. 18(2), 163-176, 2004.
[7] Taesoon Kim, Jun-Haeng Heo, Deg-Hyo Bae and Jin-Hoon Kim, “Single-reservoir operating rules for a year using multiobjective genetic algorithm”, Journal of Hydroinformatics, 163-179, 2008.
[8] Y. Mathur ,S. Nikam , “ Optimal reservoir operation policies using genetic algorithm”, Int. J. Eng Technol, vol(2), 184-187, June 2009.
[9] S. Sonaliya and T.M.V. Suryanarayana, “Optimal Reservoir Operation Using Genetic Algorithm: A Case Study of Ukai Reservoir Project”, International Journal of Innovative Research in Science, Engineering and Technology, vol 3(6), June 2014.