PRELIMINARY REVIEW OF THE OPTIMAL OPERATION OF RESERVOIR SYSTEMS USING OPTIMIZATION AND SIMULATION METHODS

F. Othman[1], M. S.Sadeghian[2], M.Heydari[3,] A.Rezaei[4]

[1]Associate professor, Civil Engineering Dept., University of Malaya, Malaysia.
E-mail:[1]*faridahothman@um.edu.my*
[2]Assistant Professor, Civil Engineering Dept., Tehran Central Branch, Islamic Azad University, Iran.
E-mail:[2]*m.Sadeghian29@yahoo.com*
[3]PhD Candidate at Civil Engineering Dept., University of Malaya, Malaysia.
E-mail:[3]*m3heydariii@yahoo.com*
[4]PhD Candidate at Civil Engineering Dept., University of Malaya, Malaysia.
E-mail:[4]*rezaei.agh@gmail.com*

Operation of reservoirs is one of the most important and complicated issues in usage of dams that the designers have had challenges with for long. One of the most important solutions is choosing the best study method as well as utilizing the best engineering techniques. By using these methods and techniques, not only the operational method is studied, but also the capacity of reservoir is estimated. The most important methods in determining the capacity of reservoir are: critical period method (mass curve, sequent peak method, working table), optimization methods or system engineering techniques (linear programming, dynamic programming) and simulation method. Optimization is a method that should result in the best answer to a problem based on given purpose and limitations defined as mathematical functions. In this method, the design parameters such as the height of the dam could be estimated using mathematical models. It is also possible to evaluate the approximate operation of reservoir, based on the dam height. This paper aims at investigating the process operational studies of reservoirs. Also, it investigates the potentialities as well as the limitations of computational methods of reservoir functions in simulation and optimization methods. Finally, necessary guides in order to choose a suitable method as well as evaluating the results will be suggested.

Keywords: reservoir operation; simulation; optimization;DP;LP

Introduction

The resource constraints and increasing demand for water in different areas such as: drinking, agriculture, industry, electricity, environmental issues, compels more studies on water researches and planning. These studies focus on water research planning and management in order to store water and operate the reservoirs in a designable way. In order for this to be implemented, three stages called identification, explanatory, and elaboration are taken into account for operational investigations.

First of all, the options are identified, investigated and evaluated based on the identification stage criteria after that, the height of dam and other parameters of chosen options are determined using optimization and simulation techniques. The main aims of the explanatory are to select the final option as well its type, height, volume, the normal water level as well the economic justification of the project. So, based on the criteria and taking into account the strong and weak points of options, the final decisions on the options are made. Also, the main aim of the elaboration stage is to determine the details of the project are implemented easily. In addition, the behavior of reservoir in its lifetime is simulated. Furthermore, the best operational method of the reservoir to meet its goals is also determined. The result of these investigations is included in the elaboration stage report in the form of rule curves and relevant guidelines. The general trend of the reservoir studies is depicted in figure 1. As it can be seen in this fig., having defined the possible options and calculated the reservoir function, the capacity of the reservoir and type operation should also be defined. To solve such programming models, there are two main methods which are: system optimization and system simulation.

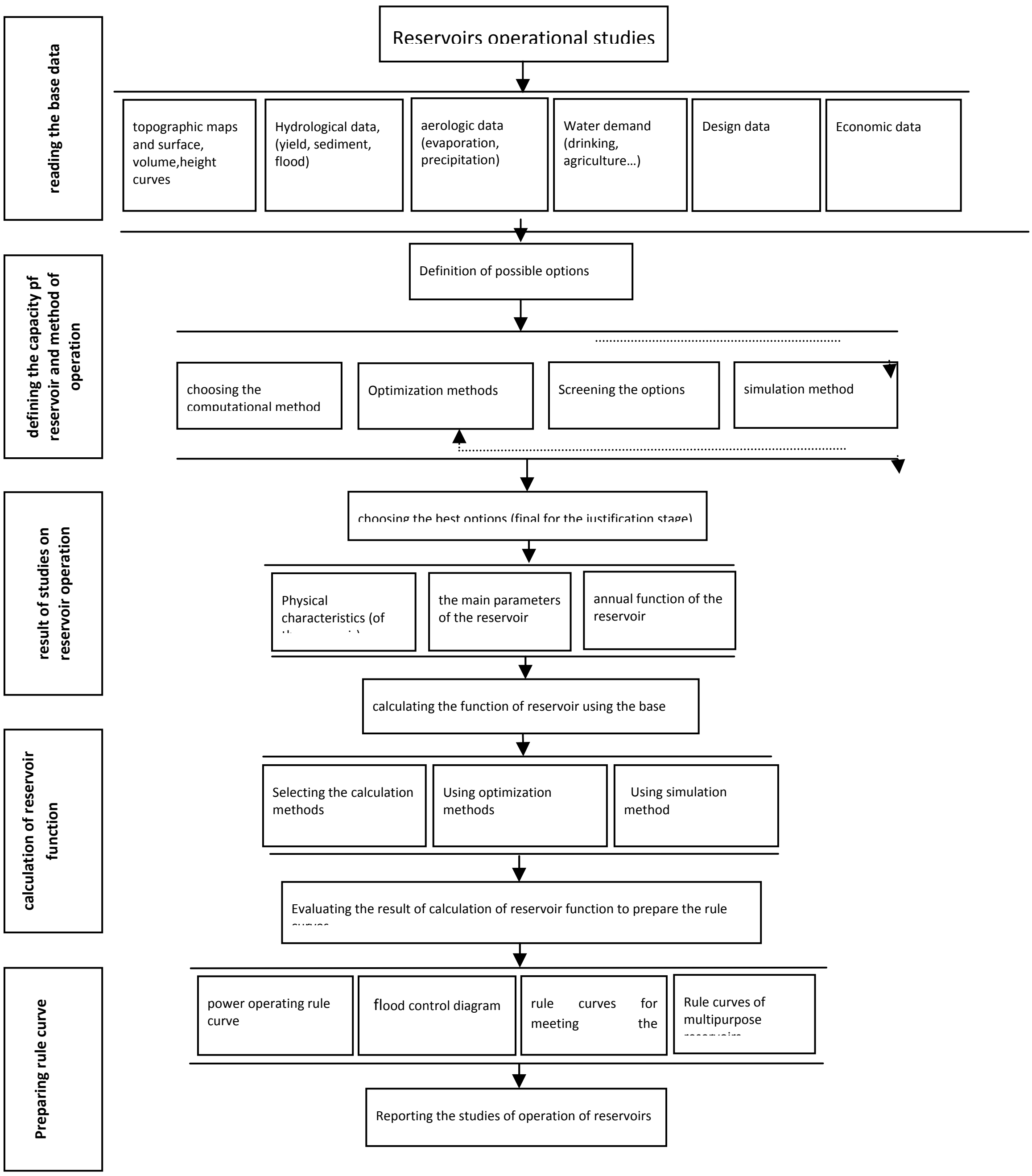

Figure 1: operational studies of reservoirs

Reservoirs operational calculations

Optimization:in many cases there are complex processes with multi variables decisions. Optimization makes it possible to model a process mathematically along with its constraints. Then the model could be optimized using classical optimization methods or the more modern ones like artificial intelligence. The programming models usually consist of at least one objective that should be maximized or minimized. These functions rank the answers or the plans. What is more, the objective model is almost always ascalar function. That is, regardless of the number of expressions the dimensions of expressions should be homogeneous. For instance, maximizing irrigation water demands (m^3/year) and hydropower water demand (mWh/year) could not be simultaneously being considered as one objective function. The optimal answer for a programming problem is a plan that shows the maximum or minimum amount of the objective while satisfying all constraint.

The general structure of a base model that constitutes the base of most of optimization models for the operation reservoirs is as follows:

Min Z: ∑losst (Rt , Dt , St)(1)

Subject to:

St+1=St - It – Rt – Et – It
(t=1, 2, ... , n)(2)

Stmin≤ st≤ Cap
(t=1, 2, ... , n)(3)

0≤Rt≤Rmaxt(t=1, 2, ... , n)(4)

St, Et, Lt, Rt≥0(5)

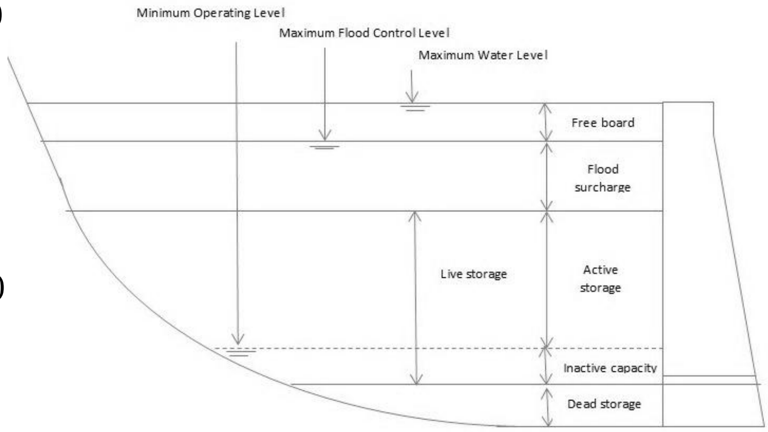

Figure 2: allocating the capacity of reservoir to different volumes

Where: (Eqs. 1~5), Z: objective function, Loss t: the cost of operation in month t which depends on the outlet need and the reservoir storage capacity in month t, Rt: outlet of reservoir in month t, Dt: water demand in month t, St: the storage capacity of reservoir in month t, N: number of intervals for programming, Smin: minimum volume water storage in reservoir, Cap: total volume storage of water in reservoir, Rmaxt: maximum outlet from reservoir in the duration of t, Et: amount of evaporation from reservoir in month t, Lt: amount of water leaking from reservoir in month t and It: amount of inlet to the reservoir in month t. (From Karamouz, M .et al. (2003)).

In the objective function of this model, the total loss in the operation period is minimized. Different types of loss functions have been proposed for the optimization of reservoir operation models which are mostly based on a function of water deficit to meet the demand and the difference between the current storage and the design storage of water of the reservoir in every month. The loss of failing to meet the demands is calculated by comparing the total released water with the total needs of the system.

In short, the advantage of the optimization method is to reach an optimum answer and the availability of a specific way for optimization for many types of problems including linear programming.

Optimization, on the other hand, has some constraints as well. For example most water systems aredimensionally large and very difficult to be optimized. Also, most non-linear algorithms need an initial answer and the speed of convergence to the optimum answer depends on the on the initial private answers. The most usual optimization models usually in the operation of reservoirs are linear programming model (LP) and dynamic programming model (DP).

Linear programming: inoptimization, allformulas including objective function constraints could be presented as the first exponent of variables. Such problems are called linear programming. In other words, in LP the objective function and the constraints are linear functions of design variables. These programminghas been used for many years in the optimization of water resources systems. This is mostly because most scientific problems are presented in linear programming frame.

Dynamic programming: in some problems, the variables depend on time. Such occasionsare called DP. Some optimization problems require multistage decision. Such problems consist of many parts. Each part could be optimized separately .It should be noted that large and complicated problems could be divided into smaller parts in which case they could be solved easily by DP.

Advantages:

1. Dividing a complex problem to simpler problems.
2. Suitable for long- term decision (problems in which the decisions are made sequentially).
3. Able to solve linear and nonlinear problems and multi-purpose variables.
4. Able to formulate accidental problems (this is the characteristics of the most water resources system).
5. Is a safe method in reservoir operational programming (as they depend on time periods and multi-stage decision making
6. Suitable for large-scale reservoirs (with capacity of more than 50% of average annual flow).

Constraints:

1. Lack ofdisciplined computerized solution and a specific method to solve a prob.
2. Cures of dimensionality (the number of cases will increase exponentially with the increase of variables and constraints.
3. Hardlyused for problems with many constraints (usually cases with more 3 groups of variables could be solved easily.
4. Every stage needs separate decision.
5. Inseparable functions cannot be formulated in DP problems suchas:x1x2+x2x3+x3x4+…
6. It is not possible to switch the maximization of a function to the minimization of the function (because the sign of factors will be changed)

Simulation: simulation methods could not be considered as optimization methods.It is the best way to investigate the operation of a system regarding the operational policies. The simulation could be done called (certain method) or could be done based on probabilistic statistics which is called (statistical method).

Simulation technique is a process helping the researchers to forecast, compare and optimize the result of their decisions and functions. Therefore, it is a story tool to test the decisions made by decision makers in a short period of time and minimum error. Logical calculation cost and the possibility of collecting evaluating data of these models have made them very popular in programming and managing the water resources systems to evaluate these systems both qualitatively and quantitatively. Example of their usage could be :annual hydropower yield , decreasing the maximum flood , providing irrigation needs(Direct problems) as well as determining the rule curve (reverse problems)The simulation methods are widely capable of solving problems with complete non- linear formulas and constraints , while optimization models cannot solve such problems.

It is also worth mentioning that in most cases the optimization models could be replaced by simulation models because reaching an answer which is close to optimum answers in water resources systems modeling could roughly be as valuable as the optimum answer.

Simulation models: In general, simulation models are classified into two categories, continuous and discrete. The continuous systems show the status of the system at each point of time. In discrete systems the changes could be investigated in some points of time. Another classification oh these models is certain and probabilistic categories. In certain models, the uncertainties in parameters and hydrological, variables are not taken into account. These models are usually used for initial decisions and comparing different options. One of the most well-known certain simulation models is ANN. If the system is subject to accidental inputs or occurrences or produces them inside, the model is known as contingent model. Uncertain simulation models consist of certain and probabilistic models and some probabilistic characteristics is (such as river discharge) could be considered in them. Uncertain simulation models usually use such information as probabilistic variables distribution function, number of their iteration in each interval and alteration interval, and the results are usually in form of probability. One of the commonplace methods of uncertain simulation water resources systems is Mont-Carlo simulation. In this method, regarding the statistical characteristics accidentals variables of the system, an amount is produced for each variable accidentally and based on this produced amount, the output such as average standard deviation and the probability distribution function are estimated by the system.

Usages and Advantageous:

1. Availability of data for simulation is usually much less costly than data for a real system.
2. After making the model, it could be used over and over to analyze the projects
3. This method is a strong, ideal and fast tool to evaluate the function of systems and projects in water resources.
4. With regard to computer software and hardware advancement, the usage of these systems would increasingly expand.
5. These methods can be used in the analysis of all systems even if the input data are incomplete.
6. In some cases the only way is to find a problem. For instance:

- When the algebraic analysis is impossible (uncertain, dynamic and complex system)
- When testing in the real world is not possible (deficit in function, uncertain systems, high cost and risk),
- Due to constraints in optimization method, using would not be possible,
- When there are no mathematical models to optimize the system.

Constraints:

1. As they are not optimization method, they are usually used to get answers which are close to optimized answers.
2. In practice, to simulate water resources problems, the reaction area next to the optimized point is roughly level and extensive.
3. As there is a possibility to be trapped in a local optimum answer, the experience and judgment of analyst play an important role in answer recognizing the general optimum answer from the local optimum answer.
4. The simulation is not highly accurate and it is not possible to calculate the extent of this inaccuracy.
5. Some simulation models are costly because it takes a long time to fund and make them.
6. One of the problems of simulation is that sometimes after a long time and hard

efforts it may result in answer which is very far from the best answer.

For example, the function of a reservoir could be simulated based on the operational regulations so that the benefits of irrigation and the annual hydropower production are determined. In this case, the operational regulations could be determined as the answer of optimization model for the given system.

To do so, the inlet flow to the reservoir, evaporation rate and the irrigation needs are selected as the input data of the simulation model. Also, volume, area and height formula of the reservoir, the volume continuity formula and soil moisture balance formula are selected as the physical formulas and constraints of the system. Furthermore, the reservoir discharge policies and the rule curves are the operational regulations and finally, the amount of discharge from the reservoir for irrigation, hydropower energy and flow regulating would be the output of the system.

Results and Conclusion

A- Choosing the best option:In equal conditions, an option would be better that: 1- Selecting the criterion for a suitable place for the reservoir is mostly based oncomparison of the amount of retrievable water from the equal height of the reservoir. 2- The reservoir with higher storage efficiency would be better. 3- In equal conditions has a lower flow volume.4- Has a lower rate of loss with equal retrievable water. 5- Has a lower implementation cost

B- Choosing the method of calculation:1-the best solution for one problem is different from another, so the chosen method should be ableto solve the problem in the best way. Therefore, the capabilities and constraints of the methodsshould be considered.2- Thebest method to solve an algorithm for each constrained optimization model depends on the specific form of the objective function and constrains equations. 3- Choosing the method of calculation would also be different regarding the system development stage. The previous implemented project in a place could act as constraints in choosing the method of calculation.4- The rate of accuracy needed in the study of project purposes would be another important factor to choose the method of calculation.5- In small problems, more methods and techniques could be applied which is merely due to the limitation of the number of variables and other constraints.

C- Conclusion:1 -There is not one single pervasive method to solve constrained optimization models. Therefore, researchers would like to model the physical economic systems of water resources with one or more competent method. If the prepared mathematical expression could not provide the best description of the system, this would act as a source of error in the real project. Another source of error is the incapability in minimizing and mathematical formulation of all purposes planning, technical, economic, political uncertainties. Therefore, each mathematical programming model would merely be an approximate description of a real water resource system in the best status. The answer would only be optimum for the prepared model and would not necessarily be optimum for the real problem. 2 -Following of the using of optimization method, the simulation method could be used to design the reservoir and to provide the necessary water for the project, taking into account the indices produced by the simulation model. The most important indices of choosing the project are as follows: 1- the average long-term deficit of each of needs. 2- The annual amount of water which can be regulated. 3- The reservoir storage efficiency. 4- Annual overflow rate. 5- Evaporation loss rate. 6- The gross benefit project implementation.

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