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Optimum Dams Reservoir Operation Considering hydropower Demands Using Dynamic Programming and Compared by Meta Heuristic Methods (Case Study Dez Dam)

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Abstract

The optimum dams reservoirs operation problem has been noticed by scholars for many years and because of this point, different optimization methods have been evaluated for finding the optimal solution of this issue. optimum dams reservoir operation especially for Dez dam, with considering the dynamic conditions (variable) for supplying the hydropower demand, has been noticed so little since now that it is done in this study by using dynamic optimization algorithm (DP) with considering the whole time variation for Dez dam reservoir. In this study, the dynamic programming method with backward approach, is used to define the release amounts for optimizing the hydropower operation of Dez dam reservoir. Process of data analysis has been done by coding in MATLAB environment and also using the spreadsheet Software's like Excel. To solve the reservoir hydropower operation problem, the stock amount at the end of period t is considered as the decision variable. According to the definition of problem, there is the possibility to change this variable in the range of (830-3340) million cubic meters. The accuracy of results and also the amount of objective function, depend to discretization method. According to this point, the most accurate answers of objective functional in discretization with range length 10 for periods of 5, 20 and 40 years, will be equal to (7.41, 20.78 and 45.7) million cubic meters respectively. Eventually to evaluate the dynamic programming method for solving the optimum dams reservoir operation problem, the results of this method has been compared by extra heuristic methods such as(ACO, PSO and GA) algorithms in solving optimization problems, and its results has been stated.

Key words: Dez dam, Dynamic programming, Hydropower operation, Optimization

Introduction

Today the optimum reservoirs operation water is as one of the most important issues in water engineering. The issue of the exploitation including reservoirs and pipes connected together is used to provide the required water of irrigation, agriculture, and hydropower. The aim of the research operation is to find optimum reservoirs in order to provide the regional water and to study the hydropower background due to plant powers. With regard to the increasingly need of man to energy and also by taking into account the consequences of the use of fossil energy to produce energy, there is tend to utilize the hydropower production in recent decades. So far the different methods is used to achieve the maximum optimization of dams. Among these algorithms can be dynamic programing (DP), evolutionary algorithms as Genetic Algorithm (GA), swarm optimization algorithm (PSO), ant colony optimization algorithm (ACOA). At first before the complementation of dynamic planning by Bellman (1957), Meas (1946) and Little (1995) proposed the idea of using stage planning to operate the reservoirs. In Iran Momeni and Rezaei proposed the model the operation of the reservoir by using the dynamic programming. In this research by assuming that the process of monthly reservoirs of river, the transition probability matrix between different states have been used and the good results achieved. Models are based on discrete DP developed by Fontane (1982), Mays and Bedient (1982), Bennet and Mays (1985), Supangat (1985) and Taur (1987) to determine the best strategy for water storage. Chang and Chen (1998) used the Genetic Algorithm with real coding and binary optimization model to flood control of reservoirs. In the first of the studies carried out, Daniel (1981) and Red (1985) analyzed the different methods used in the issues of storage management in which among them, the dynamic programming is the best. Young and Red (1999) proposed the hydropower system in Newsland which provide power generation successfully and optimized the release of water in the system. In 2000 and 2004, the deployment of neural networks (Zeinali and Story, 2016), fuzzy theory and stochastic processes are used for reservoirs management. Mousavi,& Karamouz (2004) and Borhani&Moradi and Afshar& Moeini (2007) used Multi-Colony Algorithm ACOA to solve the problems of 10 reservoirs. Borhani and Mortazavi (2008) studied the operation methods for optimization. Socha and Dorigo (2008) suggested the new revision of Ant Colony Optimization that was able to optimize at the continued environment. Moradi and Borhani (2009) showed the operation optimization in one-reservoir system in 504 months by providing algorithms (EMPSO) and comparison with PSO and GA and ACOR. Cheng and Wang (2008) used the combination of chaos and genetic algorithms to solve the hydropower optimization and proposed Chaos Genetic Algorithm (CGA). Afshar Moeini (2008) paid attention to reservoirs operations. The maximum - minimum Ant Colony Algorithm (ACOA), Ant System Elite Algorithm (AS_{elit}), Ant System Rank Algorithm (AS_{rank}), are the algorithms in which the results compared. This study is conducted especially for Dez Dam and at the result the maximum - minimum Ant Colony Algorithm is selected as the best algorithm. Borhani and Moradi (2011) carried out the operation of complicated, multi- reservoirs systems by using Ant Colony Optimization Algorithm (ACO_R) and the obtained results from the Genetic Algorithm were compared. The results showed that the proposed algorithms with increasing the numbers of decision variables, as well as increasing the time of calculation would encounter with decreasing the optimization and could not solve the complicated problems related to water reservoirs. In order to overcome to these problems, they introduced special techniques and used ACO algorithm which make decrease the time of calculations and improve the results noticeably. From the most recent research is carried out in reservoirs operations, jothiprakash & Arunkumar researches by using a non- linear planning model in optimization and by taking into account the water requirements downstream used the four algorithms. Borhani and Moradi (2014) proposed an evolving comparative analysis of artificial neural networks and the study to reinforce the probabilistic optimization system. In the last study carried out in the country Ghodoosi and Asadi Pooya studied the operation of water reservoir of Dez by using the dynamic programming and the data

were compared with heuristic techniques. The results showed this method had better performance than heuristic method, in terms of computing time and finding optimized values. According to the above mentioned, this study is intended to use DP method in hydro power sectors in which it was successful in providing water reservoir. In this study the results of the study of Ghodoosi and Asadi Pooya (1393) is used and carried out the complementary studies to provide dynamic programming in operation of reservoirs by integrating the studies. In the table 1 showed the results and achievements of the previous researchers in case of optimizing the reservoir.

Table 1. Showed the results and achievements of the previous researchers.

Researchers	Year	Methods	Results
Yang and red	1999	Dynamic programming (DP) model for hydropower system	Power Optimum production rate of release water
Meas	1946	Dynamic programming model	Dynamic programming model Proper operation
little	1959	Dynamic programming model	Dynamic programming model Proper operation
Momeni and Rezaei	1387	Dynamic programming model	Determine the best strategy for water storage
Fontane and mays	1982	The Model based on discrete DP	Determine the best strategy for water storage
Bennet and Mays and Supangat	1985	The Model based on discrete DP	Determine the best strategy for water storage
Taur	1987	The Model based on discrete DP	Determine the best strategy for water storage
Chang and Chen	1998	Genetic Algorithm with real coding and binary	optimization the flood control of reservoir
. Socha and Dorigo	2008	Ant Colony Algorithm	Optimum Operation of water storage in the continued environment
jothiprakash And Arunkumar	2013	Using a non- linear planning model	Optimum operation hydropower production by taking into account the water requirements downstream
Borhani and Moradi	2014	comparative analysis of artificial neural networks	Reinforce the probabilistic optimization of Multi storage system

In this study, DP models have proposed for optimal utilization of Dez Dam Reservoir with regard to energy production. Most results is possible by specifying values of optimal water released from the reservoir during the operation. In this study, level of reservoir water volume is intended as a decision variable. In order to solve the problems of hydro power reservoir utilization, the amount of storage at the t period is considered as a decision variable. In order to show the model, by taking into account of 251 units, the operation of 5, 20, 40 years is examined. Then the tables of TSD values were calculated for different modes and the minimum values during periods of 5 and 20 and 40 years has been calculated.

Materials and Methods

General Characteristics of the Dam

Dez Dam is the first dam in a series of multi-purpose dams which constructed on the Dez River and its structures has been located and exploited at 23 Kilometers northeast of the city Andimeshk. Before construction of the dam the devastating floods damaged the downstream and the farms each year. Dez River water stems from the heights of Oshtoran Mount, Ghalikoh, and part of the Zagros Mountains and its sub- branches made the Bakhtiari, Tireh, Marboreh Rivers. With the construction of Dez dam, there is a lake, 65 kilometers long, and ultimate capacity of 3 billion cubic meters of water. The main purposes of the construction of the dam are flood control, water management for irrigation and agriculture and provide force to generate electricity. This kind of double-arch concrete dam with a height of 283 meters is thin walled. At the time of founding is the world's sixth dam in its height. A capacity of 2510 million cubic meters of water in the reservoir of the dam and the average of operation during 40 years is 5303 million cubic meters. Due to the volume of the tank, the maximum and minimum values of water storage during operation are 3340 and 830 million cubic meters. The amounts of minimum and maximum of the monthly release water downstream are 0 and 1000 million cubic meters. The dam irrigates 125,000 hectares of downstream lands. In table 2, the overall profile of Dez is presented and the figure 1 is shown an overview of the dam and its location.

Table 2. the overall profile of Dez dam.

Characteristics	DEZ DAM
Dam Type	double-arch concrete dam thin walled
Year of operation	1341
Dam height (M)	203
Dam length(M)	212
Capacity(m. m . m^3)	2510
dam irrigates (hectares of downstream lands)	125000

Where g is the gravitational acceleration and equals to 9.81m^2/s, η is the energy efficiency, h_t is the effective head, H_t is water level in the reservoir in the period t of downstream of the plant. The tank volume curve - for Dez is defined in (4) as follows:

Where s_t is the amount of water stored in the tank during the period of t and I_t is the amount of water entrance to the reservoir in the period t, S_{min} and S_{max} are the minimum and maximum water and r_{min} and r_{max} are minimum and maximum released water.



Figure 1, basin location map and photogrammetry of dez dam.

Proposing the Dynamic Programming (DP)

The dynamic programming is an optimization method used for a set of algorithms when the sub-problems are reviewed frequently. This method was introduced by a mathematician Richard Bellman in 1953. The method in mathematics and computer science is known in which used in writing optimized algorithms by removing a sub-optimal implementation of several problem. The definition of dynamic programming in Mathematics and Computer Science is different, so that the method have higher proficiency in computer science as it eliminates the repetitive calculations while in mathematics the dynamic programming may reduce memory space. The dynamic programming is similar to division method and solve the problems by combining the answer of sub – questions. In order to create a dynamic programming we should turn a problem to sub-problems and determine the state and decision variables vectors and define the specific decision function. In DP the solving problem is defined by a recursive equation as (8):

1. $$f_i^{*n}(S_i) = \min_{x_i}\left\{C_i(S_i, x_i) + f_{i+1}^{*n-1}(S_{i+1})\right\}$$

In this equations f is recursive function, S is state variable and x is decision variable. With regard to the proposed method, in order to determine the release values of optimized operation of Dez Dam Reservoir, we used the dynamic programming with retrogressive approach. The recursive function is defined as (9):

2. $$F(s_t, Q_t) = \min\{F(s_{t+1}, Q_{t+1}) + TSD_{min}\}$$

Since DP model is a discrete model, the reservoir capacity would discrete from 830 to 3340 million cubic meter to decide each month the amount of stored water in the level. In cases in which the water input and storage is more than 3340 we should spillage the water. The continuity equation of water in each month is defined as (10):

In which the I_t is the amount of water entering the tank per month, S_t is the storage water in t month and S_{T+1} is the amount of storage water in the next month and R_t is the amount of released water, in which the overflow water.

Modeling and Results

In order to solve the problem of reservoir hydro power operation, the amount of storage at the end of t period is determined as decision variable. According to the definition of problem, there may change the yield of variable (3340 and 830). The accuracy of results and the objective function value are depend upon the discrete decision variables. At first in order to show the efficiency of model, taking into account the length of the interval 251 units, they studied the 5, 20 and 40 years operations. To this end, we used the software programming in MATLAB in two parts. The first part is the main program in which is responsible the main function of the dynamic programming (Main. M) and the other part is the function that used to enter the initial parameters. (Initial .m)

Initial function

This function is only for reading data and was used to enter it into the app. In this function the input function, demand, the initial water volume, the minimum and the maximum of reservoir and other initial values are added in periods of 5, 20 and 40 years.

The Main Program

For this purpose, the initial tables of releasing are formed in terms of flow and volume. Then the tables of TSD are calculated and the minimum of values are calculated in periods of 5, 20 and 40 years. At the end, the amount of objective functions and other values are showed in output. After analyses, the amounts of objective functions are 8/76, 25/85, 55/83 for the 5, 20 and 40 years operations. The figures of 2-4 showed the amount of produced energy in 5, 20 and 40 years operations.

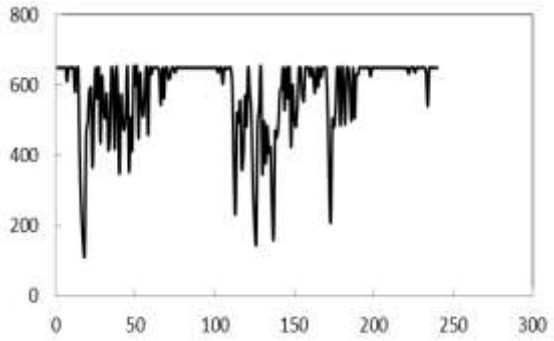


Figure 2. the release values of the dez dam storage in operation period of 20 years.

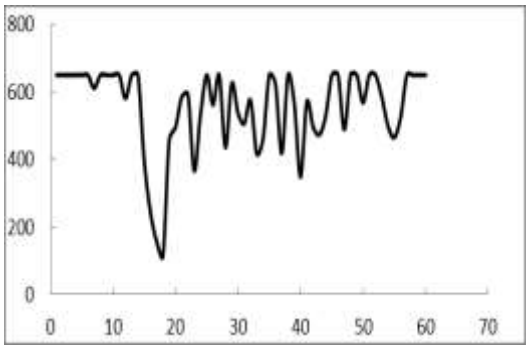


Figure 3. the release values of the dez dam storage in operation period of 5 years.

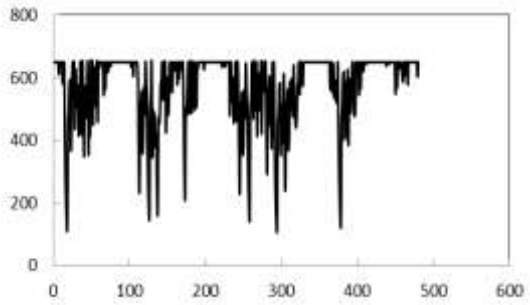


Figure 4. the release values of the dez dam storage in operation period of 40 years.

By changing the discrete decision variable we could increase the accuracy of the problem. In order to check changes in the objective function of the decision variable, the function values were calculated for different discrete intervals and is presented in table 3 and the amount and how this change in the forms is shown in figures (5) to (7), respectively.

Table 3. changes in the objective function by changing the length of the discrete interval.

	Amount of the Objective function		
During the interval discrete decision variable (save)	operation period of 5 years	operation period of 20 years	operation period of 40 years
251	8.76	25.85	55.83
62.75	7.71	21.73	47.43
10	7.41	20.78	45.73

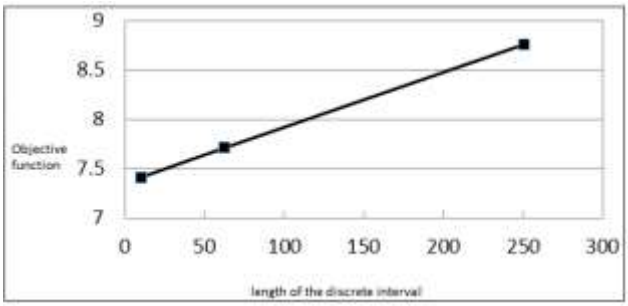


Figure 5. changes in the objective function in operation period of 5 years.

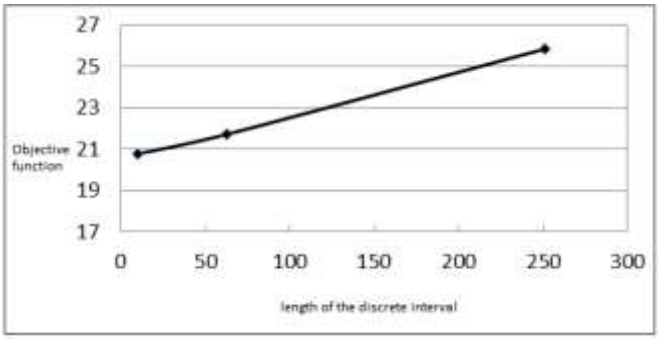


Figure 6. changes in the objective function in operation period of 20 years.

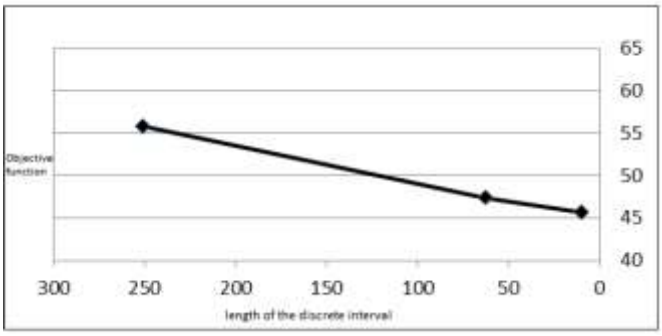


Figure 7. changes in the objective function in operation period of 40 years

According to the figures (5) to (7) we could observed that the length of the interval being less discrete, the precise of answers being more and the value of the objective function being less that means the answer is better. Although in this case the time and cost of calculation should be used.

Compare the dynamic programming with heuristic methods

In recent years the use of heuristic methods is increasingly in optimization of solving the problem. The attentions of public to use heuristic methods are using these methods in different optimization problems and it is simply implementing of these solutions. The most common of heuristic methods are Genetic Algorithm (GA), Ant Colony (ACO), and Particle Swarm (PSO). The GA is one of the stochastic optimization methods in which the population of an abstract sample (chromosomes) from the candidate of

optimization problem, is implemented to result in a good solutions. The ACO method, is a method to find the shortest way to reach the optimizations that sometimes it is very difficult and sometimes it is very time- consuming. On the other hand, the PSO algorithm is an optimized methods which by using it we could solve the answer in n-dimensions. In these conditions which the assumptions are used and by considering the initial speed of particles and the linking canal for particles, the particles would move in the motor response and calculate the results on the basis of specified in each period and the particles accelerated to those particles which have the eligibility criteria. In order to evaluate the dynamic programming to solve the optimization operation from reservoirs, the obtained results were compared with other results and are presented in table 4. In this table the maximum, minimum and the average values are summarized by the results obtained. It is clear that in order to compare the results of dynamic planning (the minimum) the basis of comparison is the best. It should be noted, despite all the advantages of this method over the heuristic methods, its disadvantage is that it requires to high volume of storage of information and challenge us with lager data. The comparisons of results are shown at figures (8) to (10).

Table 4. Comparing the maximum, minimum, and mean violation of penalty made the during 5,20,40 years periods from DP ,GA ,PSO ,ACO models by results.

Algorithm	Year of Operation	Mean	Minimum	Maximum
DP	5	7.71E+00	7.41E+00	8.76E+00
	20	2.17E+01	2.08E+01	2.59E+01
	40	4.74E+01	4.57E+01	5.58E+01
GA	5	8.62E+00	7.96E+00	9.71E+00
	20	1.42E+02	4.92E+01	4.72E+02
	40	1.71E+04	7.19E+03	3.72E+04
PSO	5	1.17E+01	8.39E+00	1.32E+01
	20	1.39E+03	8.84E+01	5.10E+03
	40	5.57E+04	2.01E+04	9.84E+04
ACO	5	8.00E+00	7.91E+00	8.06E+00
	20	3.76E+01	3.53E+01	4.00E+01
	40	1.78E+02	1.05E+02	2.75E+02

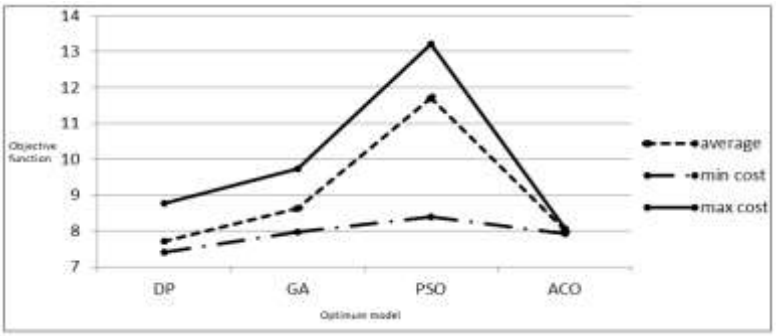


Figure 8. comparing the Objective function value in DP with the other methods of Meta Heuristic in operation period of 5 years.

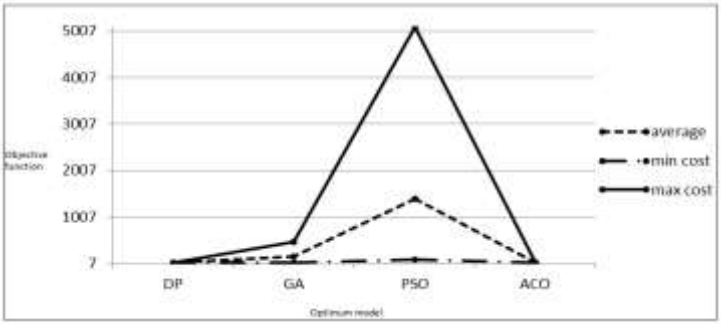


Figure 9. comparing the Objective function value in DP with the other methods of Meta Heuristic in operation period of 20 years.

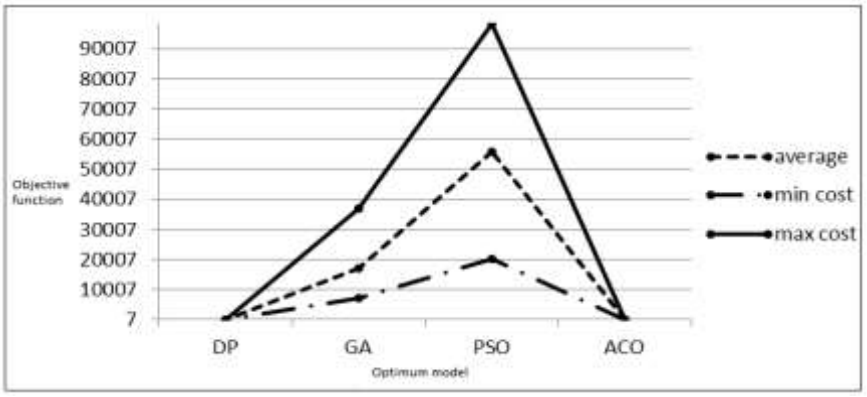


Figure 10. comparing the Objective function value in DP with the other methods of Meta Heuristic in operation period of 40 years.

As seen in the presented results the minimum values of objective function in dynamic programming is less than other methods which means the optimal method in terms of optimized answers.

Conclusion

In order to solve the problem of hydro power reservoir, the amount of storage at the end of t is considered as decision variable. According to the definition of problem, there may change the yield (830 and 3340). The accuracy of results and the objective function of discrete value is depend on the decision variables. At first in order to show the efficiency of model, taking into account the length of the interval 251 units, they studied the 5, 20 and 40 years operations. To this end, we used the software programming in MATLAB in two parts. The first part is the main program in which is responsible the main function of the dynamic programming and the other part is the function that used to enter the initial parameters. Since DP model is a discrete model, the reservoir capacity would discrete from 830 to 3340 million cubic meter to decide each month the amount of stored water in the level. The initial table of releasing are formed in terms of flow and volume. Then the table of TSD are calculated and the minimum of values are calculated in periods of 5, 20 and 40 years. At the end, the amount of objective functions and other values are showed in output. The amount of objective functions are 8/76, 25/85, 55/83 for the 5, 20 and 40 years operations. Although the discrete influence on response, sensitive analyze is carried out on the amount of discrete. The results of the analyses showed that length of the interval being less discrete, the objective function response is precise but due to the comparable results of the computation, the length is considered 10 times. With regard that the precise response of objective function at discrete with length of 10 are equal to 7/41, 20/78, 45/7 for 5, 20, 40 years, at the end in order to evaluate the dynamic programming method to solve the optimization problem, the obtained results in the discretizing 11 would be compare by the recent common heuristic methods and the results presented. According to the results, the results of dynamic programming is better that the heuristic methods. However, if the length of discrete is low during periods in DP the objective function would be better and the time of analyzes is high. Given the speed of analysis and the time required to carry out the analyses is not determined, the computational time has not been compared.

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