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# Optimizing Hydro and Thermal Power Plants Using Genetic Algorithm

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***Abstract** In recent years, various studies have been conducted on optimization of hydro and thermal power plants; however, due to the complexity of this problem, optimal operation of power systems consisting of hydro-thermal power plants with multi-purpose reservoirs, which is mostly resulting from their uncertain, non-convex, non-linear and dynamic nature, numerous simplifications and approximations have been applied in modeling these systems in order to provide the possibility of their analysis using mathematical methods. But, the result of these simplifications and approximations is distancing of the obtained models from practical operational realities of the system which limits application of their results. With progress of computational technology and advent of effective algorithms, more practical aspects of the system's real productivity can be used in optimization models. Considering the importance of this issue in the present work, a new method was presented for simultaneous long-term operational optimization of the system consisting of hydro-thermal power plants, in which main system parameters including water inflow to reservoirs of hydro power plants and energy demand of the system were uncertainly considered. In this paper, optimization of hydroelectric and thermal power plants was done using the algorithm and instructions of optimal operation were extracted.*

***Keywords:** Hydrothermal power plant, Indefinite scheduling, Genetic algorithm, Optimization.*

## I. INTRODUCTION

Appropriate scheduling plays an extremely important role in optimal operation of utility power systems consisting of thermal power plants and hydroelectric power plants with multipurpose reservoirs. This importance is due to the great savings resulted from appropriate coordination of power generation in thermal and hydroelectric power plants. Considering the low operational cost of hydroelectric power plants in contrary to thermal power plants, there is a greater tendency to use the former for meeting the existing demand. However, due to the limitation of water reserves in hydroelectric power plants reservoirs, satisfying the total demand during the operation period would not be possible. On the other hand, with growing demand, using thermal units which have higher generation cost, becomes inevitable. Therefore, the purpose of coordination of power generation in hydroelectric and thermal power plants is to make use of hydroelectric power plants in such a way that while satisfying the demand and the other limitations of the system, the use of thermal units having high operating costs, is minimized.

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Cha-an Li et al[1] have used Decomposition-Coordination method for solving the long-term optimal scheduling for hydrothermal power systems with stochastic inflows. They developed a model composed of M hydroelectric and N thermal power plants. Then the hydroelectric sub-problems and thermal sub-problems are solved by Stochastic Dynamic Planning and Non-linear Planning respectively. The results of the sub-problems are input to the main problem which coordinates the results and this is done by updating Lagrangian multiplier. The reconstruction and updating process continues till an optimal situation is achieved. L. F. Escudero et al.[2] solved long-term hydraulic generation system considering stochastic inflows to reservoirs, using scenario analysis technique. The modeling of the system is linear. Stochastic is also applied to the model through creating different scenarios for inflows to reservoirs. Then through tracker model 1, the optimal result of stochastic problem is found. The developed model has been used in Iberdola system in Spain. Ruey-Hsun Liang, [3] proposes a short-term generation scheduling at Taiwan power system using neural network theory. In fact, with analogy of system equations with a Hopfield artificial network and solving them, the global optimum is achieved. Teegavarapu et al, [4] use a nonlinear model with integer variables for real time scheduling of hydroelectric power system considering the hydraulic effect of reservoirs on each other. The proposed model has been used for scheduling Manitoba system. H. Mousavi et al, [5] studied the operating policy of multi-reservoir systems using optimal control theory (OCT). The problem has two objectives: cost and water deficit. The problem is solved based on Pontryagin principle established by Lev Semenovich Pontryagin in 1962. J.A. Gonzalez et al, [6] compared optimization and simulation models in a power system including hydrothermal power plants. He studied the effect of the optimization model assumptions on the accuracy of the optimal response and compared it with the response obtained from the simulations and concluded that it was accurate enough. Mohammad Z. Meybodi et al, [7] have studied the application of simulation and optimization in stochastic scheduling. Using Monte Carlo Simulation in a two-stage Stochastic Programming with auxiliary variables, they showed that for considering the uncertainty, first, the value operator is not a reasonable expectation. Second, the problem’s convergence at the real answer increases as the number of samples grows. Finally, 10 to 30 samples would suffice for most scientific problems.

## II. MATERIALS AND METHODS

The present research tries first to minimize the total cost of energy generation in a system combined from hydrothermal power plants and second to control the flood resulting from water inflows to reservoirs. The first step to that end is to define a target function and constraints, which is the main part of the work. One of the objective functions is the cost function, in which the total energy generation costs of hydrothermal power plants are defined as a cost function. The next objective function is the one for controlling the flood. This function should be identified clearly and its constraints must be defined as well.

The second step is to provide the necessary data, which could be real or artificial data. In the present research, we have used the real data.

The next step is familiarization with algorithms and code writing.

## III. GENETIC ALGORITHM

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. We can apply the genetic algorithm to solve a variety of optimization problems that 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 at the next generation.
- Crossover rules combine two parents to form children for the next generation.
- Mutation rules apply random changes to individual parents to form children.

The genetic algorithm differs from a classical, derivative-based, optimization algorithm in two main ways, as summarized in the following table1.

Table 1. Summary of Classical Algorithm and Genetic Algorithm

| Classical Algorithm | Genetic Algorithm |
|---|---|
| Generates a single point at each iteration. The sequence of points approaches an optimal solution. | Generates a population of points at each iteration. The best point in the population approaches an optimal solution. |
| Selects the next point in the sequence by a deterministic computation. | Selects the next population by computation which uses random number generators. |

## IV. PROBLEM FORMULATION

The problem of optimal operation in a reservoir is formulated based on flood controlling and cost minimization. Figure 1 shows the schematic of a water dam system.

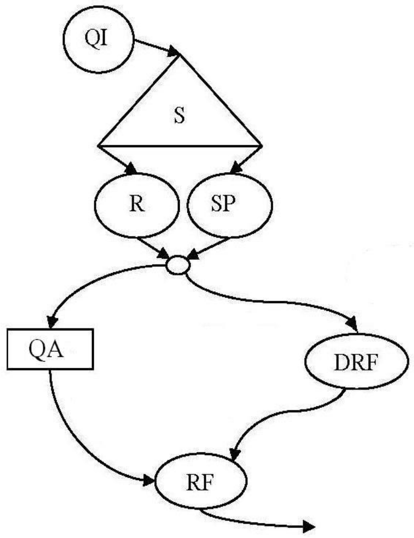


Figure 1. Schematic of a Water Dam System

In this system, the inputs are assumed as net flow and the effects of evaporation and penetration are not considered.

In figure 1, QI flows into the dam and the stored water (S) is allocated to agriculture, industry and drinking (totally showed as QA). SP, R, DRF and RF represent reservoir spillway, dam abandonment through outlets, river direction flow which is the consumption surplus of total output water and returned water from drinking, industrial and agricultural use plus river direction flow respectively which constitute the downstream water right. There is a minimum water right necessary for meeting environmental needs.

Problem formulation

The problem for optimal operation in a reservoir is formulated on the basis of minimizing the costs of meeting needs and flood controlling. The functions are as follows:

(1) First objective function (costs):

Minimize:

$$Z1=\sum_{j=1}^{n}\sum_{T=1}^{36}PT_{T,j}\times COT_{T,j}+\sum_{i=1}^{k}\sum_{T=1}^{36}PH_{T,i}\times COH_{T,i}+\sum_{T=1}^{36}PX_{T}\times COX_{T}+\sum_{T=1}^{36}PI_{T}\times COI_{T}$$
$$+\sum_{i=1}^{k}\sum_{T=1}^{36}SLUPR_{T,i}\times COSLUPR_{T,i}+\sum_{i=1}^{k}\sum_{T=1}^{36}SLDOR_{T,i}\times COSLDOR_{T,i}+\sum_{i=1}^{k}\sum_{T=1}^{36}SLQD_{T,i}\times COSLQD_{T,i}$$

Where objective function statement are energy generation cost of thermal power plants, energy generation cost of hydro power plants, output cost (calculated with minus sign), input cost, and penalty for violation of command curve upper and lower limit and unsupplied water respectively.

The parameters used in the above equations are as follows:

$PT_{T,j}$ is the amount of generated energy in Tth month from jth thermal unit

$COT_{T,j}$ is energy generation cost in Tth month from jth thermal unit

$PH_{T,i}$ is the amount of generated energy in Tth hydro from ith thermal unit

$COH_{T,i}$ is energy generation cost in Tth month from ith thermal unit

$PX_{T}$ is the output energy of hydroelectric system into adjacent systems in period T

$COX_T$ is the output energy cost of hydroelectric system in period T (with minus sign)

$PT_T$ is the input energy of hydroelectric system from adjacent systems in period T

$COT_T$ is the input energy cost of hydroelectric system from adjacent systems in period T

$SLUPR_{T,i}$ is the violation of command curve upper limit of reservoir ith in Tth period

$COSLUPR_{T,i}$ is penalty for violation of command curve upper limit of reservoir ith in Tth period

$SLDOR_{T,j}$ is the violation of command curve lower limit of reservoir ith in Tth period

$COSLDOR_{T,j}$ is penalty for violation of command curve lower limit of reservoir ith in Tth period

$SLQDT_{T,i}$ is water shortage in reservoir ith in Tth period

$COSLQDT_{T,i}$ is penalty for water shortage in reservoir ith in Tth period

$n$ is the number of thermal power plants

$k$ is the number of hydro power plants

In final result of cost function, the amount of penalty is subtracted from objective function and the remainder is announced as cost.

The second and third objective function (flood controlling):

For controlling the output from reservoir in monthly intervals, so that no flood occurs, parameter $FLD_{T,i}$ is defined as flood in the blow statement:

(2) If $DRF_{T,i} \geq QF_i \Rightarrow FLD_{T,i} = DRF_{T,i} - QF_i$

(3) If $DRF_{T,i} \langle QF_i \Rightarrow FLD_{T,i} = \phi$

Where:

$QF_i$ is the average flow rate of river of 30 input scenarios.

$$QF_i = \frac{\sum_{j=1}^{30}\sum_{i=1}^{36} QI_{T,i,s}}{30 \times 36} \tag{4}$$

Therefore, there should be:

$$Minimize Z2 = \sum_{T=1}^{36} FLD_{T,1} \tag{5}$$

$$Minimize Z3 = \sum_{T=1}^{36} FLD_{T,2} \tag{6}$$

## V. RESULTS

In this research, in order to formulate a long-term operation optimization model for hydro-thermal power plants, coding was done in MATLAB software. After analyzing sensitivity, efficiency of using GA in developing this model was investigated and the results were extracted. In genetic algorithm, population size, combination probability, mutation and so on had a great effect on minimizing or maximizing the target function. In this work, sensitivity analyses were performed on size of different populations, mutation probability and other cases and the best mode was selected. The results were as follows:

Considering that the model used multi-objective genetic algorithm, more than one response, i.e. a group of responses, were introduced, which are shown in the following diagrams:

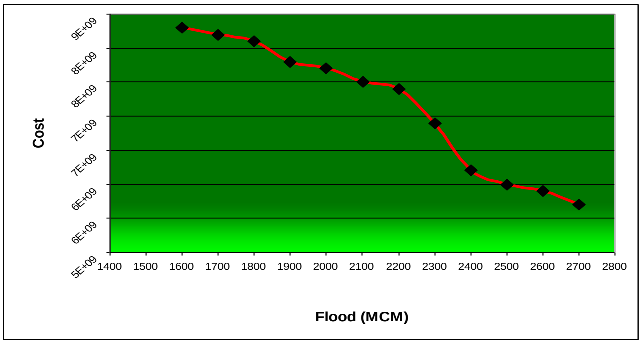


Figure2. Diagram of flood in terms of cost

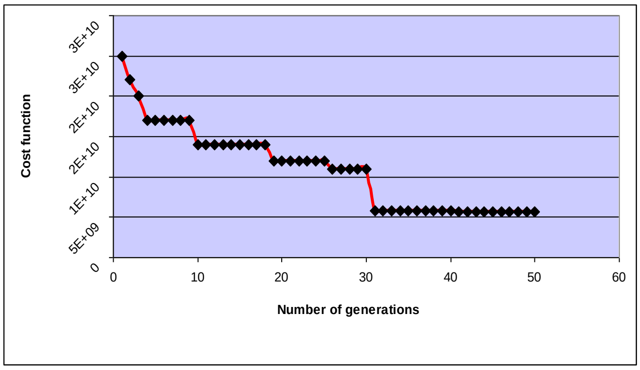


Figure3. Diagram of evolution in target function of cost

After implementing the model, the responses were given using the following diagrams and the proposed parameters were compared as shown below. First, costs resulting from the proposed model were compared and HTCOM-III model and its real value were obtained. This point is given in Figure 4.

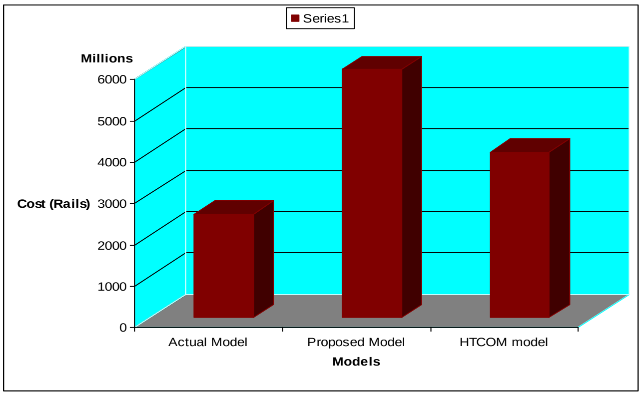


Figure4. Diagram for costs comparison

## VI. DISCUSSION

1. If some really uncertain parameters enter process of model solution algorithm, reliability of their responses will increase. For example, in the case of an optimization model, if target function is of cost type, higher model uncertainty would lead target function to obtain more cost than the model in which there is uncertainty but is not considered. However, reliability of the responses of the first model would be higher. On the other hand, uncertain models, especially those that are modeled using Mont Carlo method, do not result in a certain response for a problem; but, the response is stated in the form of concepts like expected value or standard deviation.

2. Optimization method of scenarios, the solution of which was made practically impossible by the abundance of uncertain parameters, was capable of solving big problems with many uncertain parameters.
3. Although increasing model's uncertain parameters increased its cost, the model performance was much better than real performance, which was due to the point that this model considered the system as a whole and regarded all the interactions in both time and place dimensions.
4. In this work, an efficient method was presented for considering stochastic uncertainty of parameters. However, there is another type of uncertainty relating to the parameters, considering of which would complete the model in terms of uncertainty. Fuzziness of parameters is another type of uncertainty in parameters which adds to the model capabilities.
5. Considering and calculating noise value can model uncertainty in a better way.
6. Considering penetration value can help in making a more realistic reservoir continuity equation.
7. Considering other values than cost and flood control has great influence on decisions made by the model. One of the important goals can be quality of supplied water for different needs.
8. Considering demand supply as a separate target function can help in some way to make costs more realistic.
9. Production cost of hydro or thermal power plants has non-linear relationships. Considering the nonlinear relationship of production cost and its application to the model are among important steps which should be taken for the model improvement.

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