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Optimization of Mang[a]la Hydropower Station, Pakistan, using Optimization Techniques

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Abstract. Hydropower generation is one of the key element in the economy of a country. The present study focusses on the optimal electricity generation from the Mangla reservoir in Pakistan. A mathematical model has been developed for the Mangla hydropower station and particle swarm and genetic algorithm optimization techniques were applied at this model for optimal electricity generation. Results revealed that electricity production increases with the application of optimization techniques at the proposed mathematical model. Genetic Algorithm can produce maximum electricity than Particle swarm optimization but the time of execution of particle swarm optimization is much lesser than the Genetic algorithm. Mangla hydropower station can produce up to $59*10^9$ kWh electricity by using the flows optimally than $47*10^8$ kWh production from traditional methods.

Keywords: Mangla Reservoir, Hydropower, Optimization techniques, PSO.

1 Introduction

Optimal management and utilization of water resources is a serious and main issue in water scarce countries, which is also mainly affected by changing climate. Optimal allocation of water resources for adaptable use is also critical and complicated subject for water managers, because of inter-reliant and non-linear relationships. Consequently, optimal allocation of water resources, which is usually mathematical based, is a foremost area of study now a days in water resources advancement [1]. Computer based complex processes were established in 1970s to deal with such kind of problems [2,3]. Researchers exploited a lot of versatile techniques, linear to dynamical programming, to solve the water allocation and reservoir operation problems in the past [4,5]. Abundant water resources studies have made the use of these techniques for various problems [6,7]. Though, the nonlinear approaches require a lot of information about constraints and objective function, which make them inefficient.
Genetic algorithms (GA) are quest methods relay on natural selection mechanism that combine the fittest artificial survival with genetic operators. A randomly generated chromosome population, which represents the initial solution of the possible problem, goes through the GA. GA is an optimal search strategy, of a set of likely possible designs rather than a single design; that permits the Genetic algorithm to keep a multipoint observation on several locations within the solution space simultaneously, resulting in a high possibility of discovering the global optimum [8].

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Numerous studies have utilized this technique to solve the water resources problems and found that GA is a promising technique [1,9,10]. Oliveira and Loucks (1997 a,b) used genetic algorithm to figure out the multi-reservoir operations [11], whereas Wardlaw,[12,13] and Sharif (1999;2000) also used GA in multi reservoir operation and concluded that GA is a robust technique and replacement of conventional optimization techniques. Van Zyl et al (2004) combines the GA with a hill climber search method and used it for optimal water distribution [14]. Wang et al (2011) utilized the GA for water resources problems and found it a comprehensive, versatile and best technique to find the optimal solution [15].

Another significant optimization technique named as Particle Swarm optimization (PSO), developed by Kennedy and Eberhart (1995), is becoming popular to solve optimization problems [16]. Numerous studies utilized this technique to solve water related problems and found it robust and best for getting best solutions in water resources [17].

Pakistan is facing water shortage issues from last decade and Mangla reservoir is one of the major power generation source in this electricity scarce country. Optimal electricity generation and utilization of available water in this reservoir is a complicated and critical issue now a day. To the best of authors knowledge, recently no work has been done in this area to get the optimal hydropower generation from the hydropower stations. There is a dire need to utilize available water resources and to get optimal electricity generation for the electricity short country. The presented study is a try to get optimal hydropower generation from Mangla hydropower station by applying two numerous GA and PSO algorithms at newly developed mathematical model for Mangla hydropower station.

2 Study area

Mangla hydropower is installed at Mangla reservoir situated at Jehlum river, which is a major tributary of Indus river. The Jehlum River receives water from major four of its tributaries named as Neelum, Poonch, Naran and Kanshi Rivers and dispose into the Indus River. The Mangla reservoir and hydropower station is the only one existing station, currently at the Jehlum River and meeting point of aforesaid tributaries. The hydropower is installed at the Mangla Dam, which is 147m high and about 3000m in length with a water storage capacity of about 9.12km^3. The installed hydropower station has a capacity of 1000MW with maximum efficient conditions. Mangla reservoir and hydropower station are shown in Figure 1 as below.

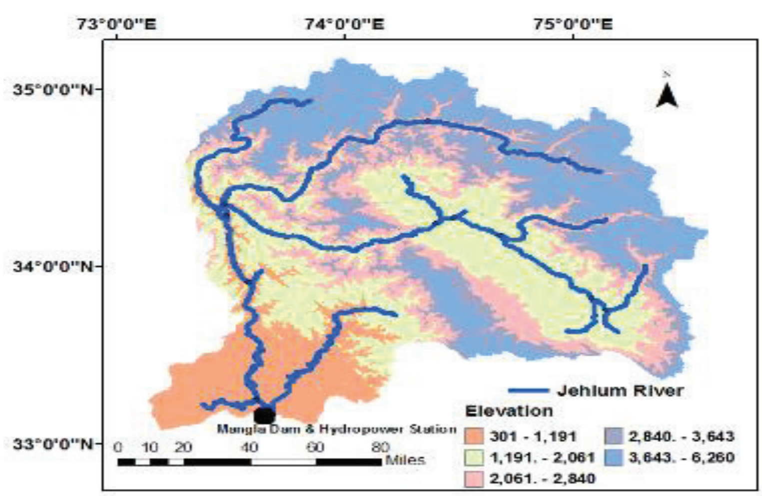

Figure 1: Location of the Hydropower station

3 Methodology

3.1 Mathematical model

A mathematical model has been developed and utilized for Mangla Hydropower station. The model consists of mainly constraints and objective function. Reservoir water level is taken as constraints and maximization of the hydropower as an objective function by the model. The objective function of the model and constraints are given below

$$E_{max} = \sum_{k=1}^{T}\sum_{k=1}^{M} A_k q_{kt} H_{kt} \Delta t \quad (1)$$

Whereas the constraints are given as below
Water balance equation

$$V_{k,t+1} = V_{kt} + (Q_{\lambda\kappa\tau} - Q_{kt}) * \Delta t \quad (2)$$

Reservoirs discharge limits

$$Q_{kt,min} \le Q_{kt} \le Q_{kt,max} \quad (3)$$

Reservoirs storage volume limits

$$V_{kt,min} \le V_{kt} \le V_{kt,max} \quad (4)$$

$$N_{kt,min} \le N_{kt} \le N_{kt,max} \quad (5)$$

Where T is total time period within a year, T=12 ,M is the number of total reservoirs, A_k Coefficient for Power generation , E is maximum hydropower generation , $Q_{\lambda\kappa\tau}$ is Inflow of reservoir k at time period t, m^3/s, H_{Kt} k reservoir average head at time period t, m, $V_{K,t+1}$ reservoir k volume at the end of time period t, $Q_{Kt,min}$ / $Q_{Kt,max}$ are minimum/maximum k reservoir outflow at time period t, m^3/s , $V_{It,min}$ / $V_{It,max}$ minimum/maximum k reservoir volume at time t, $N_{It,min}$ / $N_{It,max}$ are Minimum/maximum k hydropower installed capacity at time period t

3.2 Genetic algorithm

GA is an optimal search strategy, of a set of likely possible designs rather than a single design ; that permits the Genetic algorithm to keep a multipoint observation on several locations within the solution space simultaneously, resulting in a high possibility of discovering the global optimum [8].. The flow chart that shows the working of genetic algorithm is given below in Figure 2.

3.3 Particle swarm optimization

Kennedy and Eberhart (1995) developed particle swarm optimization technique (PSO) for optimal solutions. Particle Swarm Optimization technique has an initialization and an evolution phase. In initialization phase, population is initialized using randomly distributed particles within the search, whereas in evolution phase particle adjust their positions according to the most successful particles within the space till the termination of the met criteria.

Virtual particles move in D-dimensional space in the PSO model. Every particle keeps best solutions in its path named as pbest and best location met by the swarm named as gbest. The next movement of individual particle is controlled by a velocity vector and influenced by gbest and pbest.

The position of the ith particle in the search space is indicated as $k_i = k_{i1}, k_{i2}......, k_{iD}$ and velocity is indicated as $V_i = v_{i1}, v_{i2}........v_{iD}$. The position and velocity are updated according to equation 6 and 7 given below

$$v_i^{t+1} = w * v_i^t + c_1 rand_1(pbest_i - k_i^t) + c_2 rand_2(gbest_i - k_i^t) \quad (6)$$

$$k_i^{t+1} = k_i^t + v_i^{t+1} \quad (7)$$

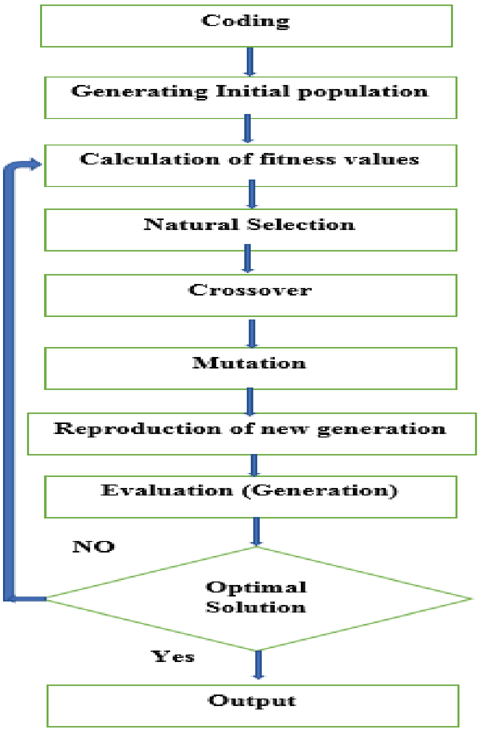

Figure 2: Flow chart of Genetic Algorithm

Where $k^{min} < k_i^{t+1} < k^{max}$, i=(1,2,3….swarm/population size);t=number of reproduction steps; v_i^t =speed vector of k particle in ith reproduction; w is inertial weight; c_1 and c_2 are learning rates; $rand_1$ and $rand_2$ are independent uniformly distributed random variables within [0,1] range; $pbest_i$ and $gbest_i$ are best solution reached by particle k and swarm respectively.

4 Results and discussion

Inflow and outflow data of the Mangla reservoir since 1960 to 2010 was collected from Water and Power Authority of Pakistan. Log three Pearson technique had been applied at this data to determine the year with maximum, average and minimum flows in the Mangla watershed. The year with maximum flows named as rainy year and with average flows named as average rainfall year. Similarly, the year observed with minimum flows named as Dry year. The results obtained after the application

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of different algorithms at these data series are presented in Table 1 and for PSO are shown in figure discussed below.

4.1 Genetic algorithm

Results obtained after the application of genetic algorithm at rainy, average and dry year data series are presented into Table 1 for energy output and time of execution of algorithm. Results depict that upto $59*10^8$ kWh electricity could be produced by using GA for rainy year and time required for this execution is about 16.82 seconds. Results depict that we can produce maximum electricity for rainy, average and dry years by using GA. Table 1 presents that time of execution is more than PSO for rainy, average and dry year. Results exhibits that electricity production could be increase if we use the flows according to GA as it gives much more amount of electricity than traditional particle swarm optimization methods.

4.2 Particle swarm optimization

Results obtained after the application of particle swarm optimization technique at rainy, average and dry years are presented into Table 1 and for rainy and average year in Figure 3. Results depict that electricity production using particle swarm optimization is lower than GA but time of execution for PSO is much lesser than GA. Moreover, GA and PSO produced more electricity than traditional method. Figure 3 presents upto $53*10^8$ kWh of electricity using PSO with outflow and water level shown for rainy year. It is also evident from the Figure 3 that upto $33.7*10^8$ kWh electricity can be produced from average year with water release and water level given in the Figure 3.

Table 1: Electricity production using different algorithms

Algoriths	**Energy Output (10^8 kWh)**				**Execution Time (s)**			
	Rainy Year	Average Rainfall year	Dry Year	Average	Rainy Year	Average Rainfall year	Dry Year	Ave rage
Traditional Method	47	25	20	30.66				
GA	59	43.8	38.2	47	16.82	16.76	16.68	16.8
PSO	52	33.7	28.3	38	3.88	3.84	3.81	3.84

5 Conclusion

The present study focusses on the optimal electricity generation from the Mangla reservoir in Pakistan. A mathematical model has been developed for the Mangla hydropower station and particle swarm and genetic algorithm optimization techniques were applied at this model for optimal electricity generation. Results revealed that Genetic Algorithm can produce maximum electricity generation as compare to Particle swarm optimization, but the time of execution of particle swarm optimization is much lesser than the Genetic algorithm. Results revealed that the electricity production increases with the application of genetic algorithm and particle swarm optimization techniques at proposed mathematical model than traditional techniques. Results are evident of up to $59*10^9$ kWh electricity production with optimal flows that is more than $47*10^8$ kWh, that we are getting using traditional method in Mangla hydropower station. Results revealed that by managing our discharge and water level equivalent to optimal water level, we can produce maximum electricity. More benefits can be obtained in the form of power production with the application of Genetic algorithm at mathematical model than PSO for Mangla hydropower station.

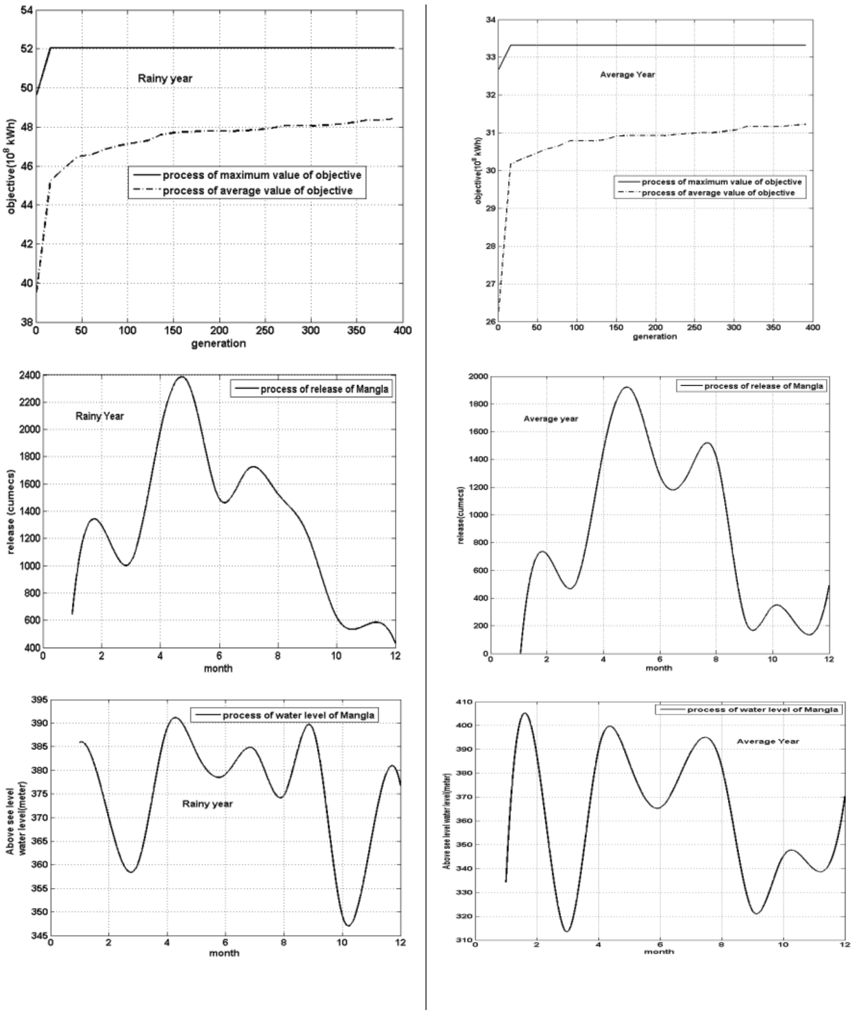

Figure 3: Results of PSO for rainy and average year for Electricity production, Water level and Water release

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