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Optimization Of The Operating policy Of The Multipurpose Hirakud Reservoir By Genetic Algorithm

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***Abstract*: -** Genetic Algorithms is an optimization technique , based on the principle of natural selection, derived from the theory of evolution , are popular for solving parameter optimization problem. The main aim of this study is to develop a policy for optimizing the total release of water for irrigation, power generation and industry purpose in different months with different constraints during lean period of the multipurpose Hirakud reservoir of Odisha state in India by Genetic algorithms. The policy thus developed is compared with the current policy used by the department water resources, Government of Odisha to release the water for irrigation, power generation and industry use. The result thus found out is depicted through tables and graphs. It can be concluded that Genetic Algorithms model has the capability to perform efficiently.

Key wards: - *Genetic Algorithm, Optimization, Hirakud Reservoir*.

I. INTRODUCTION

The optimal reservoir operation policy for multipurpose reservoir should specify how the total demand of water could meet the available water in the reservoir. The operating policies are generally defined by a set of rules that specify either the reservoir target storage volume or the target release. In many practical situations, It is observed that the operating policies are established at the planning stage of reservoir to meet the planned demand like irrigation, power generation. But now a days, industrialization is one of the most important factor to improve the economic growth of a country. So the supply of water to the industries cannot be over ruled. Hence the demand and release of water for industrial purpose should be another parameter for the specific multipurpose reservoir operating model .

To obtain optimal operating rules, a large number of optimization and simulation models have been developed and applied over the past two decades. Genetic Algorithm is a robust search and optimization technique for solving complex problem. It was developed from the work done by Holland [1]. A large number of works has been reported on the application of GA for various complex reservoir problems .East and Hall [2] has applied GA to a reservoir problem with the objective of maximizing the power generation and irrigation. The optimal operating policies and release rules were also derived using GA by Olivera and Loucks [3].Wardlaw and Sharif [4] developed a GA model for a multi-reservoir system and reported that GA can be satisfactorily used in real time operations and extended the applicability to complex reservoir problem. Sharif and Wardlaw [5] developed a GA model for optimization of a multi-reservoir system in Indonesia by considering different scenarios. GA models were also successfully applied by Chen [6], Kuo et al. [7]; Ahmed and Sharma [8]; Chang et al. [9]; Anon-dominated sorting Genetic Algorithm (NSGA-II) was developed by Chang and Chang [10], to derive the operational strategies for the operations of a multi-reservoir system. Mathur and Nikam [11] optimized the operation of an existing multipurpose reservoir in India using GA, and derived reservoir operating rules for optimal reservoir operations. Hakimi-Asiabar M et al. [12] developed a self learning GA model for deriving operational policies for multi-objective reservoir system. Jothiprakash V. et al [13] derived a multi reservoir optimal operating policies using GA model and results of the GA model were then compared with conventional stochastic dynamic programming model. Recently Tripathy U.K. and Pradhan S.N. [14] developed a GA model for deriving optimal operating policy for Hirakud reservoir in India. The results obtained by GA model are compared with the current policy used by the Government of Odisha and observed that GA gives a better policy. From the above study, It is found that most of the works deal with release of water only for irrigation and power generation in reservoir system till date. In the present study an attempt has been made to derive an optimal operating policy using GA model by taking another parameter i.e. release of water for industrial purpose. The results of the GA model were then compared with the current policy used by the Government of Odisha.

II. STUDY AREA

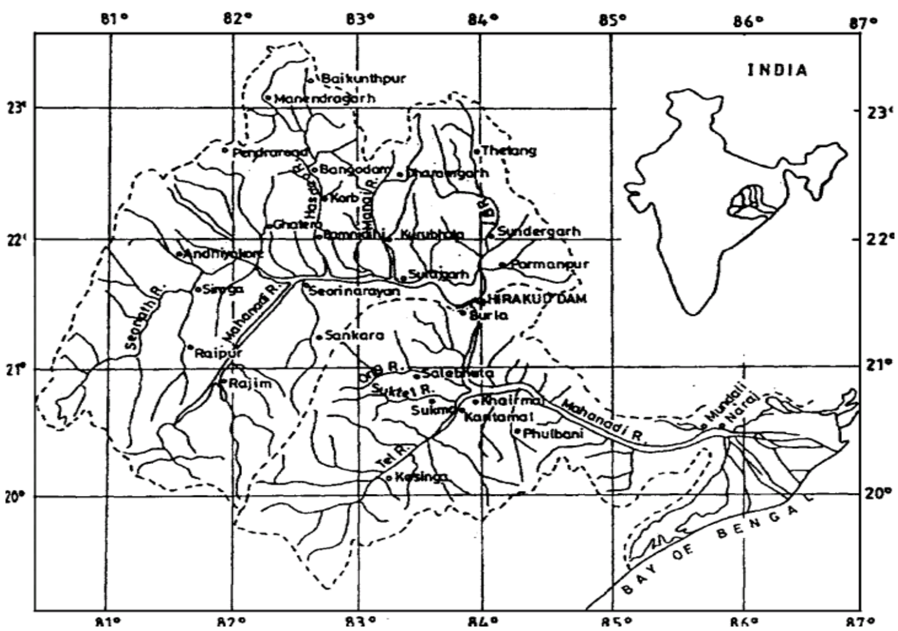
The reservoir consider in this study is the Hirakud Dam ,Multi-purpose reservoir located in the river Mahanadi at latidute 21^0 - 32' N, and longitude 83^0 - 52' E . The reservoir is constructed in the year 1956 . The reservoir required to meet irrigation demand, hydro power demand and flood control , which are different in different months. The reservoir is irrigating 1,55,635 hectors of kharif,1,08,385 hectors of rabi in Sambalpur ,Bargarh, Balangir and Subarnapur district of orissa .The water released by the power plant irrigates another 4560 km^2 of the CCA area in the Mahanadi delta. Again it generates 307 MW hydro electricity through two hydro electric controlling the river flow of 9500 power plant ie. Burla and Chiplima .The dam is also km^2 of the delta area in Cuttack and Puri district through the drainage system.

The multipurpose Hirakud dam across the river Mahanadi was constructed for flood control, irrigation and power generation. Hirakud dam is a composite structure of earth, concrete and masonry. The main dam having an overall length of 4.8 km spans between hills Lamdunguri on left and Chandli dunguri on the right sides to close the low saddles beyond the abutment hills. It has the distinction of being one time this longest dam in the world, being 25.8 km long with dams and dykes taken together.

It also has the rare distinction of forming the biggest artificial lake in Asia with reservoir spread of 743 square kilometers at full reservoir level. The reservoir has life storage of 5818 million cubic meters with gross storage of 8136 million cubic meters (mcm). Spilling can be affected by the operation of sluice gates incorporated in the concrete dam .The crest level of the spill way is at reservoir level 185.928 meter (610ft.) Both the split way contain 64 number under sluices, out of which 40 numbers are in the left and 24 number are in the right with floor at reservoir level 154.43 meters(510 ft) Each sluice has width of 3.658m(12ft) and height of 6.08m(20.34ft) .The sluices can discharge up to 0.95 million cubic meter per second .Free board is to be controlled during the filling season by the expected input capacity of the power channel and the discharge capacity of the spilling system subject to the flood control restraint.

III. MODEL DEVELOPMENT

Genetic Algorithm is a search and optimization technique based on the principle of natural selection and genetics. This is efficient, adaptive and robust search process, producing near optimal solution. Genetic Algorithm are heuristic technique for searching over the solution space of a given problem in an attempt to find the best solution or set of solution. The basic elements of natural genetics –reproduction, cross over, mutation are used in the genetic search procedure. Genetic algorithm differs from conventional optimization techniques in following ways:



(Fig-1, catchment area of Hirakud dam ,India)

1. GAs operate with coded versions of the problem parameters rather than parameters themselves .
2. Almost all conventional optimization techniques search from a single point but GAs always operate on a whole population of points(strings) .
3. GA uses fitness function for evaluation rather than derivatives. As a result, they can be applied to any kind of continuous or discrete optimization problem. The key point to be performed here is to identify and specify a meaningful decoding function.
These are the major differences that exist between Genetic Algorithm and conventional optimization techniques.
The basic genetic algorithm is as follows:
• [start] Genetic random population of n chromosomes (suitable solutions for the problem)
• [Fitness] Evaluate the fitness f(x) of each chromosome x in the population
• New population] Create a new population by repeating following steps until the New population is complete
- [selection] select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to get selected).
- [crossover] With a crossover probability, cross over the parents to form new offspring (children). If no crossover was performed, offspring is the exact copy of parents.
- [Mutation] with a mutation probability, mutate new offspring at each locus (position in chromosome)
- [Accepting] Place new offspring in the new population.
A Simple Genetic Algorithm
• [Replace] Use new generated population for a further sum of the algorithm.
• [Test] If the end condition is satisfied, stop, and return the best solution in current population.
• [Loop] Go to step2 for fitness evaluation.

In the present study, the fitness function of the GA model is minimizing the squared deviation of monthly irrigation demand, power generation demand, industrial demand and squared deviation in mass balance equation for the lean period(Jan-June). The objective function is given by the equation

Z= Minimize $\sum_{t=1}^{6}(\boldsymbol{RI_t - DI_t})^2 + \sum_{t=1}^{6}(\boldsymbol{RP_t - DP_t})^2 + \sum_{t=1}^{6}(\boldsymbol{RF_t - DF_t})^2 + \sum_{t=1}^{6}(\boldsymbol{AS_t + I_t - RI_t - RP_t -}$ **RFt**$-\boldsymbol{Et2}$

Where RI_t= Monthly irrigation release for month 't'
DI_t= Monthly downstream irrigation demand for the month 't'
RP_t= Monthly power generation release for month 't'
DP_t= Monthly power generation demand for month 't'
RF_t= Monthly release for industry purpose for month 't'
DF_t= Monthly demand for industry purpose for month 't'
$AS_t = \frac{1}{2}(S_t + S_{t+1})$= Average storage in the month 't'
S_t = initial storage in the beginning of the month 't'
S_{t+1} =Final storage in the end of the month 't'
I_t= Monthly inflow during the period 't'
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 and power generation release during the month t should be less than or equal to the irrigation and power generation demand in that month and are represented by

$RI_t \leq DI_t$ t=1,2,3,4,5,6.

$RP_t \leq DP_t$ t=1,2,3,4,5,6.

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 capacity and is represented by

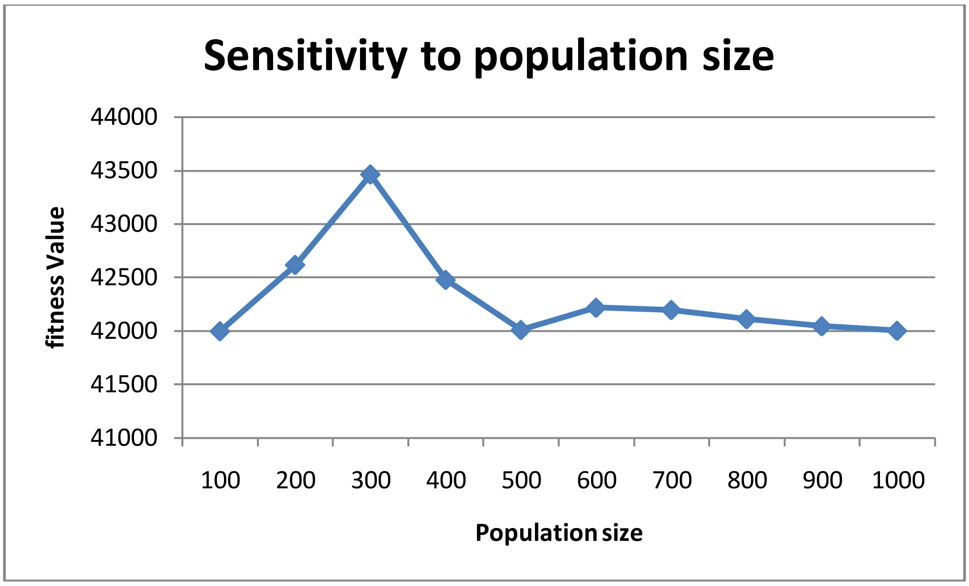
$$S_{min} \leq S_t \leq S_{max}$$

Where
S_{min} = Dead storage of the reservoir = 1814.976 mcm
S_{max} = Maximum capacity of the reservoir = 7190.856 mcm

IV. SENSITIVE ANALYSIS

Sensitivity analysis has been carried out to evaluate the effect of population size on the GA performance. All other parameters and run controls were set constant. Fig (2) shows that the best fitness value

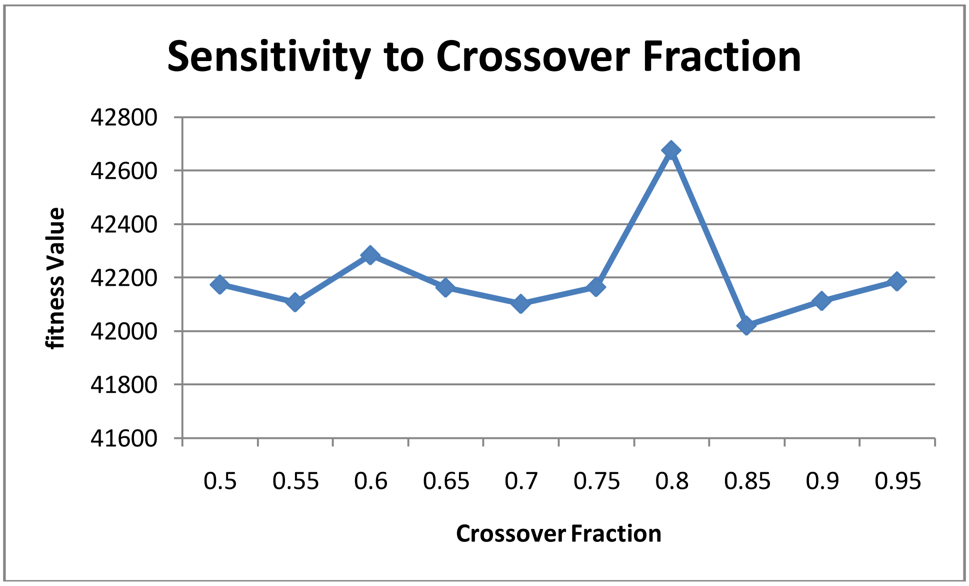
42475 is achieved at the population size 400 and is not might be good from 500 to 1000. Now by taking population size 400, sensitive analysis has been done to evaluate the effect of crossover fraction and from Fig (3) , It can be observed that the best fitness value 42676 is achieved for the crossover fraction of 0.8 . If too less values of crossover fraction are used, then the performance of GA is not so good. Again by taking population size 400 and crossover fraction .08 , sensitivity analysis has been carried out to evaluate the effect of mutation rate on the performance of GA . In this case we are getting the best fitness value as 42204 at the mutation rate 0.01.The reasonable solutions are obtained when the rate of mutation has risen except at 0.05.



(Fig-2 , Sensitivity to population size)

Table - 1, fitness values on different population size

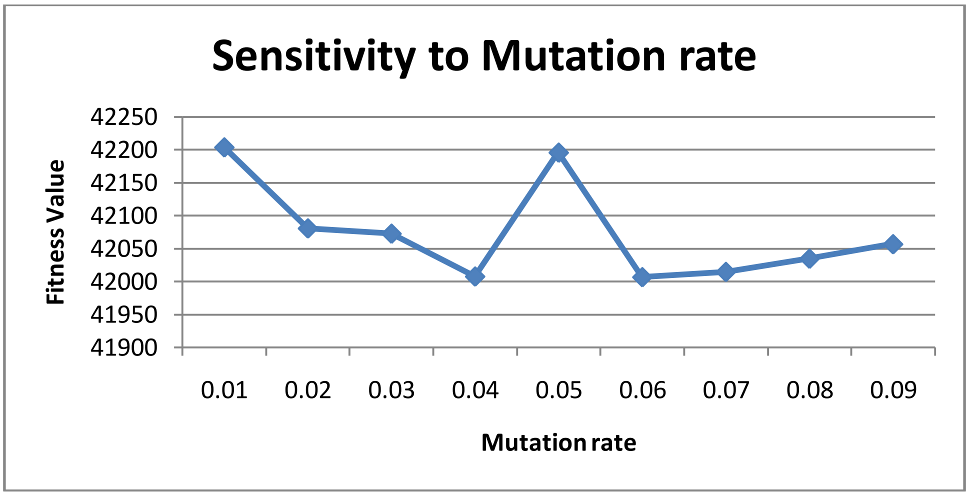
Population size	100	200	300	400	500	600	700	800	900	1000
Fitness value	41996	42615	43460	42475	42007	42215	42194	42108	42043	42000



(Fig-3 , Sensitivity to crossover fraction)

Table - 2, Fitness values on different crossover fraction

Crossover fraction	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
Fitness value	42174	42108	42284	42163	42102	42165	42676	42021	42113	42186



(Fig-4 , Sensitivity to mutation rate)

Table - 3, Fitness values on different mutation rate

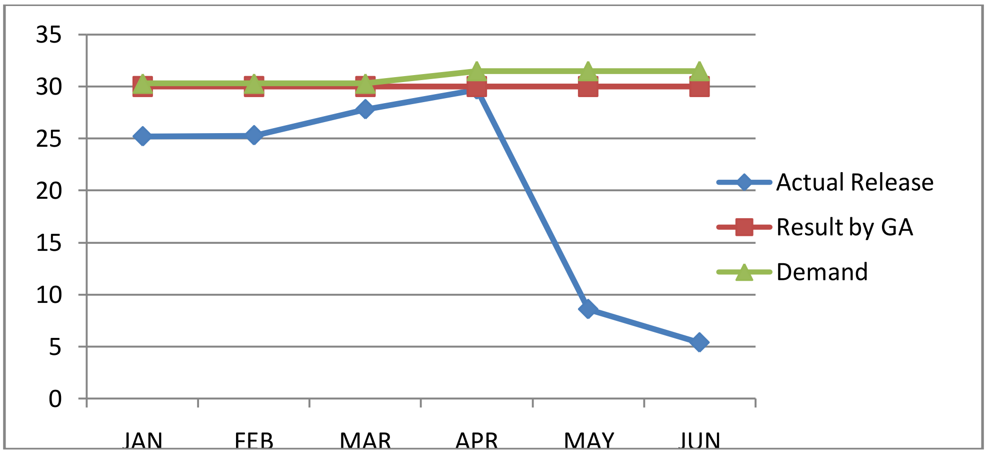
Mutation rate	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
Fitness value	42204	42081	42073	42008	42196	42007	42015	42035	42057

V. IV. MODEL APPLICATION AND DISCUSSION

GA has been applied to the above formulated model . We have encoded at MATLAB software for optimizing the above multipurpose reservoir. The use of efficiency of data are taken from the sensitive analysis and the average inflow data has been taken from the data base of water resources department of Government of Odisha in India. The important input variables in the present GA model study are the monthly irrigation demand, monthly power generation demand , monthly industrial demand and the mean storage in the reservoir. The objective of the study is to compute the quantity of water that should be released for irrigation, power generation and industrial purpose, keeping in view the minimum storage in the reservoir in that particular month. Thus 24 decision variables are considered for the lean period (Jan-June). The fitness function evaluation gives the measure of goodness of the fit of the string. After fitness function evaluation ,strings are selected based on the percentage contribution of the population fitness for mating and mutation to form the next generation by the Roulette Wheel method.

The population size in GA is one of the important parameters. It is very important for obtaining optimum population. The size of the population ranges from 64 to 300 and even up to 1000 in water resources applications. A large population helps to maintain greater diversity but it involves considerable computational cost when the full model is being used to generate performance predictions. The policy thus derived shows the irrigation, power generation and industrial purpose deficit.

VI. WATER RELEASE FOR IRRIGATION



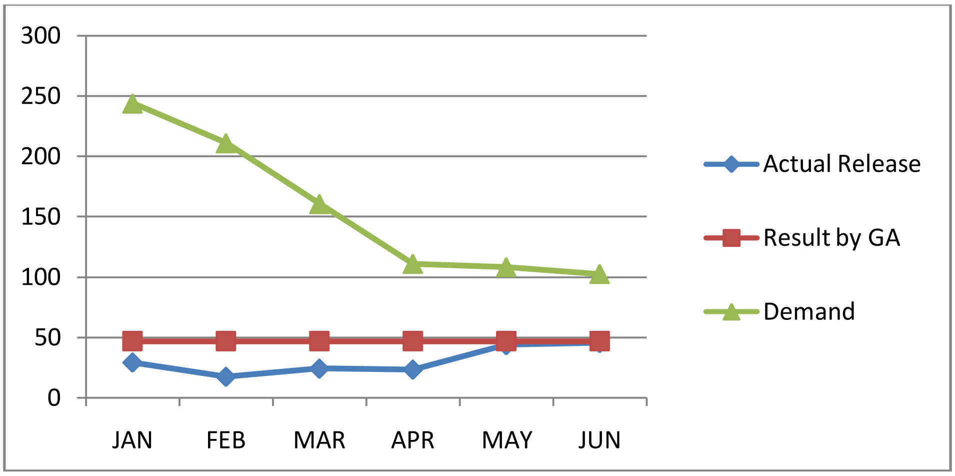
(figure-5, Water release for irrigation)

Table-4 (Release of water for irrigation)

All figures are in MAcF * 10^2

Month	January	February	March	April	May	June
Actual Release	25.2	25.3	27.8	29.7	8.6	5.4
Result by GA	29.978	29.996	29.984	29.987	29.995	29.995
Demand	30.29	30.29	30.29	31.5	31.5	31.5

WATER RELEASE FOR POWER GENERATION



(figure-6, Water release for power generation)

Table-5 (Release of water for Power Generation)

All figures are in MAcF * 10^2

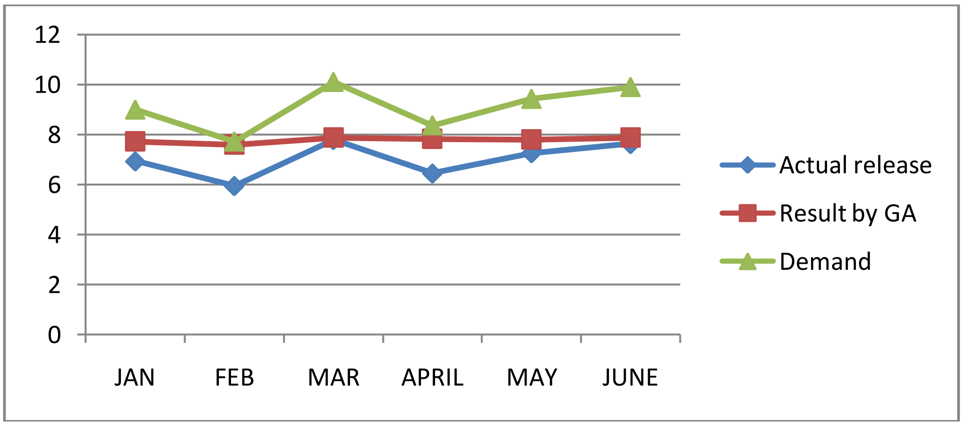
Month	January	February	March	April	May	June
Actual Release	29.4	17.6	24.3	23.5	43.8	45.5
Result by GA	47	46.995	46.987	46.99	46.99	46.99
Demand	244.14	211.24	160.71	111.0	108.2	102.6

Table-6 (Release of water for Industry Use)

All figures are in MAcF * 10^3

Month	January	February	March	April	May	June
Actual Release	6.925	5.938	7.783	6.438	7.254	7.621
Result by GA	7.72	7.59	7.88	7.82	7.8	7.87
Demand	9.0	7.719	10.11	8.369	9.43	9.907

WATER RELEASE FOR INDUSTRIAL PURPOSE



(figure-7, Water release for industry purpose)

VII. CONCLUSION

An optimal policy has been developed for release of water from the reservoir for irrigation, power generation and industrial purpose with average storage of the reservoir for a particular month t. Our policy developed through GA shows that the release of water for irrigation, power generation and industrial purpose is more than that of the release by the department of water resources, Government of Odisha, keeping strict vigil on dead storage of the reservoir. Table-4 shows the release of water for irrigation. It is observed that the result obtained by the GA fulfils 99% of the demand in the month of February which is the maximum and 95% is the minimum in the month of April. The table-5 shows the release of water for power generation. The result obtained by GA fulfils 46% of the demand in the month of April which is the maximum and 19% is the minimum in the month of January. Similarly table- 6 shows the release of water for industrial purpose . The result obtained by GA fulfils 98% of the demand in the month of February which is maximum and 79% is the minimum in the month of April. Thus the policy developed by Genetic Algorithm is far better than the policy being used by the water resources department of Government of Odisha in India.

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