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Assessment of Hydropower potential in Kulsi river basin using Non-Linear Optimization and Simulation

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Abstract: Though the North-Eastern region of our country have enough potential for development of hydropower projects, yet the development of hydropower project in this region are very limited. In this paper an attempt has been made to study the Hydropower potential of Kulsi river basin. The Kulsi river basin is located on the southern part of the river Brahmaputra. The basin is in between $25^{0}32^{/}$ N & $26^{0}\,07^{/}$ N and $90^{0}\,45^{/}$ E & $91^{0}\,48^{/}$ E. In this study, Non Linear Programming model have been developed to study the hydropower potential of the basin. The model is run for the target power reliability $\geq$ 90 %. From the study it is found that at optimal reservoir capacity 522.722 Mcm., the firm hydropower that can be produced from the project is 10.70 MW. Maximum annual power, average annual power and maximum monthly power that can be produced from the project are 252.292 MW, 155.84 MW and 44.0 MW respectively.
Keywords: Hydropower potential, Non-Linear Programming, Simulation, Reliability.

I. INTRODUCTION

For sustainable use of water resources, an efficient reservoir operation policy is very important in planning and management of water resources. The reservoir operation policy includes amount of water to be released to meet various demands in a systematic way. The water resources problems are very complex. It is not easy to formulate them into mathematical equations and have a solution. Simulation and optimization techniques are the tools to solve these complicated problems. In this paper the potential of hydropower generation from Kulsi basin is studied using system analysis techniques. The Kulsi multipurpose project was undertaken jointly by the Brahmaputra Board, Central Water Commission and Government of Assam jointly for hydropower generation, irrigation and flood moderation.

It is proposed to construct concrete dam across the river Kulsi. The proposed site for the dam is about 1.5 km downstream of Ukium village in Assam. The basin occupies the area in Kamrup and Goalpara district of Assam, also West Khasi hills and East Garo hills district of Meghalaya. Figure-1 shows the location map of Kulsi basin. The basin is surrounded by Bharalu, Kallong and Kopili sub basin in the east side, Krishnai- Dudhnoi sub-basin in the west side, West Khasi hills in the south side and the mighty river Brahmaputra on the north side. Kulsi river is a tributary of the Brahmaputra river system. The total catchment area of Kulsi river basin is 3770 Km^2. The catchment area upto dam site is 1628 km^2.

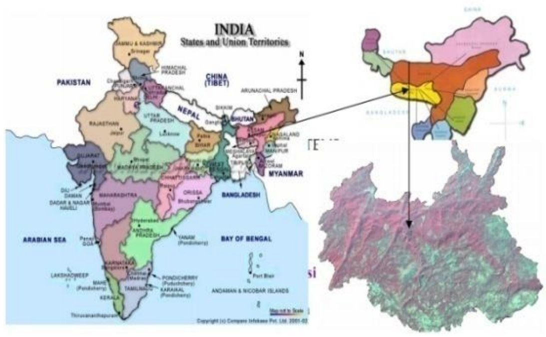

Fig-1: Location Map of Kulsi Basin

2. LITERATURE REVIEW

Water resources system analysis has now been generally accepted to provide an efficient way of answering the numerous questions regarding planning of a large-scale real life water resources system for which the conventional methods of analysis will be inadequate. The approach and appropriate technique varies from problem to problem depending up on state of development of the system and range of decision-making (Dahe, 2001). Bosona and Gebresenbet (2010) expressed that a small advancements in reservoir operation leads to a large benefits. A simulation model was developed to control the reservoir releases for power generation. Due to nonlinearities, conflicts among various objectives, the management of a reservoir system is very complex. This complexity could be overcome by optimal operation of the reservoir system by using optimization and simulation models. They extended the state of art reviews on operational management of multi-purpose reservoirs with modern advancements for real time control on a reservoir system. Sharma et al. (2015) developed a monthly time series simulation model for evaluating the performance of Ukai reservoir in Gujarat, India serving municipal, industrial, irrigation water demands, hydropower generation and flood moderation. They used simulation models for performance assessment under four different conditions and investigated the reliability, resilience, vulnerability and sustainability indices. Barrow (1998) enumerated that mathematical modelling provides a way, perhaps the principal way of predicting the future behaviour of existing or proposed water resources system. A mathematical model is a set of equations that describes and represents the real life water resources system. Application of models to real life system have improved the understanding of such systems, and hence contributed to improved system design, management, and operation. Arunkumar and Jothiprakash (2013) established a monthly simulation model for power generation and irrigation releases from a multi-reservoir system. They observed that the power generation was high under unconstrained conditions as there were no restrictions on power release. Under constrained conditions power generation was less but more reliable irrespective of extent of time. It was concluded that for lesser duration of operation reliability was higher**.** Rani and Maria (2010) revealed that when optimization and simulation models are combined together the approach gives the best results. They reviewed various literatures on simulation, optimization and combined simulation–optimization modelling approach and reported an overview of their applications. Ahmad et al. (2014) reviewed the different optimization methodologies developed for solving problems related to water resources. A real-time operational model was developed by Vedula and Mohan (1990) for multipurpose reservoir operation for irrigation and hydropower generation on Bhadra reservoir of Karnataka, India. The optimal monthly real-time operation demonstrated the relevance, applicability and the relative advantages for reservoir operation. Afzali et al. (2008) presented a multi-reservoir reliability-based simulation (RBS) model considering the integrated operation of the systems. The model employed the general algorithm of the single-reservoir RBS model. Fayaed et al. (2013) reviewed the simulation–optimization modelling techniques used to solve the critical issues relating to reservoir system. They noted that for a reliable optimization models an accurate simulation model is very essential. The combination of simulation-optimization models gives best results in reservoir managements. Application of the simulation techniques to real life problems related to rivers in India was reported in doctoral works carried out in India, e.g. Srivastava (1976), Talukdar (1999), Sarma (2005), Kotir et al. (2016).

3. METHODOLOGY

Hydrological data are collected for the study of Kulsi multipurpose project from various sources. Monthly inflow data have been collected from the Central Water Commission, Brahmaputra & Barak Basin Organization, Shillong. The monthly data series collected are classified data and permission for publication could not be obtained. Evaporation data available at the Lokapriya Gopinath Bordoloi International Airport, Borjhar, Assam, have been considered for the project. The area- capacity-elevation values estimated by Survey of India from reservoir area map have been collected from the project authority and used for the present study. Gross command area of Kulsi project is 37908 Ha. An area of 32800 Ha (net irrigable area) is to be irrigated using the water of Kulsi reservoir. The monthly irrigation demands in various months for crop area obtained from irrigation management plans- plan-1, plan-2 and plan-3 and the plan proposed by the project authority have been considered in the present study. The total annual irrigation demands for plan-1, plan-2, plan-3 and plan proposed by project authority (plan-4) are 93.282 Mcm, 97.069 Mcm, 105.825 Mcm and 49.208 Mcm respectively.

Simulation model has been developed with the help of above mentioned data and has been presented like a simple reservoir working table. In simulation, it is assumed that in any time period if water is available, then demand has to be met. Ecological, irrigation and hydropower demands are considered in this model. As per the guidelines provided by National Water Development Agency, Govt. of India, 10% of the average non-monsoon flow is to be considered as ecological demand; and this amount should be available in the downstream of river at any time. As per the National Water Policy in India, the ecological and irrigation demand are given higher priority than the hydropower demand. In Kulsi project, irrigation and power generation are compatible, i.e., irrigation yields are also available for power generation.

The application of the model is started with the assumption that the initial storage in the reservoir is 300 Mcm. It is a theoretical approach considering the worst condition. Here 39 years of monthly inflow data is used and the month of "May" is considered as the start of each water year. The best fitted equations obtained from 'storage v/s elevation' and 'storage v/s area' curves from elevation – storage – area relationships have been used in the simulation model. The model is run for the irrigation management plan-1, plan-2, plan-3 and also for cropping pattern proposed by project authority. Initially firm power is assumed as 6 MW, reservoir capacity 525.64 Mcm at full reservoir level (FRL at 115 m elevation), tail water level 51 m and plant capacity 55 MW. From these data, by utilizing simulation model, the maximum annual hydropower, power reliability, irrigation reliability, average annual power, average annual irrigation and firm power are obtained. 10 % of the average non-monsoon flow is considered as ecological demand; and this amount should be available in the downstream river at any time. With the minimum target reliability the scope to increase the irrigation supply is also obtained.

4. RESULTS AND DISCUSSIONS

The simulation model is developed for determining the irrigation and hydropower potential from the basin. Deterministic inflow, flow continuity, storage bounds, storage-area-elevation relationships, demand requirements, evaporation losses, spills, plant capacity constraints /relationships are incorporated in to the model. The simulation model is run for the target of irrigation reliability ≥ 75 % and power reliability ≥ 90 %.

Simulation model is run to see the behaviour of the reservoir under different scenarios and results are summarized below.

In the first case, the Plant capacity 55 MW, reservoir capacity 525.64 Mcm (FRL) and tail water level 51.0 m are kept constant and firm power is varied. The annual irrigation requirement for plan-1 is 93.282 Mcm. Initially firm power is assumed 6.00 MW to run the simulation model. After that the firm power is successively increases to see the changes in power and irrigation reliabilities under successive simulation run. The results of the iterations are presented in table-1. It is obeved that the firm power 10.70 MW fulfills the target reliabilities. Beyond firm power 10.70 MW the power reliability becomes less than 90% though the irrigation reliability is satisfied. Hence, the firm power 10.70 MW is best suited for reliability of hydropower and irrigation.

Table -1: Firm power vs irr. rel/pow.rel/av.ann.irr/av.ann.pow. (plan-1)

Firm power (MW)	Irrigation reliability (%)	Power reliability (%)	Average annual irrigation (Mcm)	Average annual power (MW)
6.00	96.1	96.10	93.28	166.28
7.50	96.1	96.10	93.28	165.59
9.00	96.1	94.87	93.28	163.43
10.00	95.48	94.04	92.91	161.04
10.50	95.28	91.79	92.29	157.40
10.65	94.87	91.37	91.73	156.85
10.70	**94.87**	**90.14**	**91.71**	**156.28**
10.75	94.87	89.94	91.71	155.99
10.80	94.87	89.32	91.71	155.71
11.00	94.87	88.50	91.71	154.40
12.00	91.99	78.64	87.98	146.36

The simulation model is also run for the plan-2, plan-3 and cropping pattern proposed by the project authority by changing the irrigation demands. The irrigation demands for plan-2, plan-3 and cropping pattern proposed by the project authority are 97.069 Mcm, 105.825 Mcm and 49.208 Mcm respectively. From the iterations it is observed that the firm power 10.70 MW satisfisfied the target reliabilty of irrigation and hyrdropwer for all the plans. Beyond the firm power 10.70 MW power reliabilty becomes less than 90% though the irrigation reliability is satisfied.

In the second step, firm power of 10.70 MW, plant capacity 55 MW and tail water level 51.0 m have been kept constant and the reservoir capacity is varied. For running the model initially reservoir capacity in considered 400.0 Mcm and the simulation model is run under different reservoir capacities. From the iterations it is seen that for reservoir capacity 525.64 Mcm, the target reliabilities are satisfied. The corresponding elevation for the reservoir capacity 525.64 Mcm is 115 m (FRL).

Table-2: Reservoir capacity vs irr. rel/pow.rel/av.ann.irr/av.ann.pow. (plan-1)

Reservoir capacity (Mcm)	Irrigation reliability (%)	Power reliability (%)	Average annual irrigation (Mcm)	Average annual power (MW)
400.00	91.37	74.95	86.57	136.04
500.00	94.87	88.29	91.71	152.14
520.00	94.87	89.53	91.71	155.42
521.00	94.87	89.53	91.71	155.58
522.00	94.87	89.94	91.71	155.73
522.50	94.87	89.94	91.71	155.81
522.722	**94.87**	**90.14**	**91.71**	**155.84**
525.00	94.87	90.14	91.71	156.18
525.50	94.87	90.14	91.71	156.26
525.64	**94.87**	**90.14**	**91.71**	**156.28**
530.00	94.87	90.96	91.71	156.93

Similarly, the model is also run for the plan-2, plan-3 and cropping pattern proposed by the project authority by changing the corresponding irrigation demands. From the iterations it is observed that the reservoir capacity 525.64 Mcm satisfied the target reliabilities for all plans.

To obtained the optimal reservoir capacity, optimization is done and found that the reservoir capacity 522.722 Mcm satisfied the target reliabilities. Table- 2 shows the results of the iterations for plan-1.

For fixing the plant capacity, the reservoir capacity 522.722 Mcm, firm power 10.70 MW and tail water level 51 m are kept constant and the plant capacity is varied. Table-3 shows the results of the iterations for plan-1, where the plant capacity 55 MW satisfies the target reliabilities. Since the turbine has a particular capacity, so the plant capacity cannot increase or decrease without changing the turbine capacity. Similarly, the model is also run for the plan-2, plan-3 and cropping pattern proposed by the project authority by changing the corresponding irrigation demands. From the iterations it is observed that the plant capacity 55 MW satisfied the target reliabilities for all plans.

Table 3: Summury of results of plan-1, plan-2, plan-3 and cropping pattern proposed by project authority

Particulars	Plan-1	Plan-2	Plan-3	cropping pattern proposed project authority
Firm power (MW)	10.70	10.70	10.70	10.70
Optimal reservoir capacity (Mcm)	522.722	522.722	522.722	522.722
Plant capacity (MW)	55	55	55	55
Tail water level (M)	51	51	51	51
Maximum drawdown level (M)	90	90	90	90
Irrigation demands (Mcm)	93.282	97.069	105.825	49.208
Maximum annual power (MW)	252.292	252.292	252.292	252.292
Average annual power (MW)	155.84	155.84	155.84	155.84
Maximum monthly power (MW)	44.0	44.0	44.0	44.0
Maximum spill (Mcm)	560.552	560.552	560.552	560.552
Overall power reliability (%)	90.14	90.14	90.14	90.14

5. CONCLUSION

From the model output under different scenarios without compromising the target of irrigation reliability ≥ 75 % and power reliability ≥ 90 %, the results obtained are summarized (Table-3). The firm power that can be produced from the project is 10.70 MW. The optimal reservoir capacity required is 522.722 Mcm. Plant capacity is kept 55 MW as proposed by the project authority. Maximum annual power, average annual power and maximum monthly power that can be produced are 252.292 MW, 155.84 MW and 44.0 MW respectively from the project. The overall power reliability is 90.14 %.

6. REFERENCES

[1] Asmadi Ahmad, Ahmed El-Shafie, Siti Fatin Mohd Razali and Zawawi Samba Mohamad, "Reservoir Optimization in Water Resources: a Review", Water Resour Manage (2014) 28:3391–3405 DOI 10.1007/s11269-014-0700-5.

[2] B. Sarma (2005), "Planning for Optimal Inter Basin Water Transfer", Ph.D. Thesis, Department of Hydrology, IIT Roorkee, India.

[3] B. Talukdar (1999), "Operation of a multipurpose reservoir using stochastic dynamic programming", Ph.D. Thesis, Department of Hydrology, University of Roorkee, Roorkee, India.

[4] Christopher J. Barrow, "River basin development planning and management: A critical review" World Development, Volume 26, Issue 1, January 1998, Pages 171-186

[5] D. K. Srivastava (1976). "Optimization of Complex Water Resources Systems by Screening Simulation Model". Ph.D. Dissertation, Indian Institute of Technology. New Delhi, India.

[6] Deepti Rani, Maria Madalena Moreira (2010), "Simulation–Optimization Modelling: A Survey and Potential Application in Reservoir Systems Operation". Management, April 2010, Volume 24, Issue 6, pp 1107-1138.

[7] Julius H. Kotir, Carl Smith, Greg Brown and Ron Johnstone , A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana", Science of The Total Environment, Volume 573, 15 December 2016, Pages 444-457.

[8] P.D. Dahe (2001), "Planning for optimal development of a river basin", Ph. D. Thesis, Department of hydrology, University of Roorkee, India.

[9] Priyank J. Sharma, P. L. Patel and V. Jothiprakas, "A Simulation – Optimization Approach in Development of Operation Policy for a Multipurpose Reservoir", E-proceedings of the 36th IAHR World Congress 28 June – 3 July, 2015, The Hague, the Netherlands.

[10] R. Afzali, S. Mousavi, and A. Ghaheri (2008). "Reliability-Based Simulation-Optimization Model for Multireservoir Hydropower Systems Operations: Khersan Experience." J. Water Resour. Plann. Manage., 134(1), 24–33.doi: 10.1061/ (ASCE) 0733-9496 (2008)134:1(24)

[11] R. Arunkumar and V. Jothiprakash, "Evaluation of a multi-reservoir hydropower system using a simulation model", ISH Journal of Hydraulic Engineering 20(2) · November 2013.

[12] S. Vedula & S. Mohan (1990), "Real-time multipurpose reservoir operation: a case study", Hydrological Sciences - Journal - des Sciences hydrologiques, 35, 4, 8/1990.

[13] Sabah S. Fayaed, Ahmed El-Shafie and Othman Jaafar, "Reservoir-system simulation and optimization techniques", Stochastic Environmental Research and Risk Assessment, October 2013, Volume 27, Issue 7, pp 1751–1772.

[14] T. G. Bosona and G. Gebresenbet, "Modelling hydropower plant system to improve its reservoir operation", International Journal of Water Resources and Environmental Engineering Vol. 2(4), pp. 87-94, June 2010.