

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

Correlational Analysis of Power Generations and Irrigation Water Supply in a Cascade Hydropower System

Koshy P.S.¹, Prince Arulraj G.², Brema J.³

Research Scholar, Karunya Institute of Technology and Sciences, TamilNadu, India¹

Professor and Dean, Karunya Institute of Technology and Sciences, TamilNadu, India²

Professor, Department of Civil Engineering, Karunya Institute of Technology and Sciences, TamilNadu, India³

ABSTRACT: The aim of this paper is to correlate the auxiliary power generation from an irrigation reservoir, impounded by a barrage, with the power generation of its upstream hydro power project in a cascade generation system. The area considered for the study is the Pamba Basin- Maniyar Reservoir of the Pamba Irrigation Project, Kerala Irrigation Department and Kakkad Hydro Power Project of Electricity Board, Kerala State. In a water year from the 1st June to 31st May, irrigation period spans from November to May in the Project. As the tailrace of the upstream Hydro Electric Plant exceeds the irrigation demand, even in the peak irrigating months of January and February there is a little surplus water that can effectively be drawn for power generation. It is hypothesized that there is surplus inflow which can effectively be used for power generation. A Fuzzy Rule Based model is developed and the outputs are compared with the real time data.

A water year is divided to two Seasons – irrigation and non-irrigation- and rules are developed for both based on the real time data for five years from 2009-2014. In the FRB model the inputs considered are the generation in units of the upstream Kakkad Hydro Electric Project, the monthly runoff of the catchment, the irrigation release, spill from the barrage and the power generation in the downstream Small Hydro Electric Project (CUMI-SHEP) is considered as the output. As the storage of a reservoir impounded by a barrage is very limited, it is not taken into account. The results obtained shows that the surplus for power generation from the FRB model are satisfying the real time data.

KEYWORDS: Maniyar barrage, cascade system, Kakkad Hydro electric project (Kakkad-HEP), Carborandum Universal Madras India Ltd. Shep (CUMI-SHEP), Fuzzy rule, Membership function, MATLAB

I. INTRODUCTION

Reservoirs form a major water resources system and their optimal operation is a very important area of water resource planning and management, as the interrelationship between some of the variables is nonlinear in nature. Conflicting and complementary uses of reservoir storage have to be scientifically addressed and managed for the efficient and effective water resources management. Multipurpose reservoir operation involves interactions and trade-offs between purposes, which are sometimes complementary but often competitive or conflicting. Due to the temporal variation of inflows and multipurpose demands, the task of allocation of available water becomes more complex. With the growing pressure on available resources, the problem of conservation and allocation has assumed importance in recent days. The application of system analysis to reservoir system design, operation and management is considered as one of the most important aspects of water resources engineering (Biswas, 1976). The evaluation of current operating rules of existing reservoirs or forming operation rules in case it is absent, is very important to meet the changing demands according to the public needs and objectives.

An operation or release plan is a set of rules for deciding how much quantity of water can be made available for each purpose, under various conditions for meeting the conflicting demands. System analysis models help to

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

- Decide the reservoir storage capacities and establish operating policies during the pre-construction planning;
- Evaluate the operating plans of existing reservoir systems;
- Govern the water allocation systems involving water rights and agreements between water suppliers and users;
- Forecasting management strategies and operation plans; and
- Perform real-time operations

Civil engineering, when compared with other engineering disciplines, is fundamentally different in the sense that available theories never fit the actual design problem. This is because each civil engineering project is, by and large, unique; hence, there is almost never a chance to test a prototype as in other engineering disciplines. As a consequence, there is uncertainty in application of theoretical solutions to civil engineering projects and is large. In spite of the scientific knowledge now available, great uncertainty concerning the application of the knowledge to actual design problem still remains, primarily due to the uniqueness of each design problem in civil engineering, and the use of subjective judgment and relevant “rules of thumb” is unavoidable. This is why civil engineers so quickly found a strong affinity with fuzzy set theory. Moreover, our engineering problems are constraint satisfaction problems. How the designer deals with this uncertainty is crucial, because the standards of safety required by the general public regarding civil engineering constructions are extremely high. The designer has to make decisions in spite of the high uncertainty he/she faces. There by, these complexities, uncertainties and vagueness in decision making in real problems provide the main motivation for the use of fuzzy concepts. It is proven by the experts that the fuzzy concept is a useful tool and can be effectively applied for the problems in civil engineering in order to arrive at the optimal solution.

Yeh (1985) observed that, despite considerable progress, the research relating to reservoir operation has been very slow in finding its way into practice. The managers and reservoir operators are often uncomfortable with the sophisticated optimisation techniques used in the models, which are made much more complex by the inclusion of stochasticity of hydrologic variables. The fuzzy logic approach may provide a promising alternative to the methods used for reservoir operation modelling, because, the approach is more flexible and allows incorporation of expert opinions, which could make it more acceptable to operators. Panigrahi and Mujumdar [1] developed a fuzzy rule based model for the operation of a single purpose reservoir. The model operates on an ‘if – then’ principle, where ‘if’ is a vector of fuzzy premises and the ‘then’ is a vector of fuzzy consequences. This study concludes that by fuzzy based reservoir operation model the complex optimization procedure can be avoided, linguistic statements based on expert knowledge can be incorporated and the operators feel more comfortable in using this model. Suryanarayana T.M.V., Mihir Kemkar [2] developed a Fuzzy Rule Based (FRB) model for obtaining the optimal reservoir release. The results obtained shows that the release obtained from the FRB model are satisfying the demand completely for the period of study and there is significant amount of water saving, when compared with the actual release. Sahil Sanjeev Salvi [3] developed an optimal reservoir operation model using fuzzy Inference System (FIS) and reveals that fuzzy logic model based on MATLAB is very useful for irrigation water release corresponding to the maximum level of satisfaction and more comfortable for operators.

The application of fuzzy sets theory can provide a viable way to handle situations when problems with objectives are difficult to define due to imprecision. Out of the two types of Fuzzy Inference System (FIS) named Mamdani type and Sugeno type, the fuzzy inference process named Mamdani’s fuzzy inference method has been adopted as it represents the output more realistically.

In modelling of reservoir operation with fuzzy logic, the following distinct steps are planned with the aid of MATLAB package.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

II. FUZZY OPERATION MODEL

In modelling of reservoir operation with fuzzy logic, the following steps are followed in order.

Fuzzification of inputs:-The first step in building a fuzzy inference system is to determine the degree to which the inputs belong to each of the appropriate fuzzy sets through the membership functions. The input is always a crisp numerical value limited to the universe of discourse of the input variable and the result of fuzzification is a fuzzy degree of membership generally between 0 and 1. The problem of constructing a membership function is that of capturing the meaning of the linguistic terms employed in a particular application adequately and of assigning the meaning of associated operations to the linguistic terms. Here, membership functions are constructed for the upstream generation, Irrigation, Runoff, secondary generation and spillage- where the crisp inputs and output variables are transformed into fuzzy variables through membership functions based on linguistic terms such as 'low', 'medium', 'high' etc.

Formulation of fuzzy rule set:- Based on expert knowledge, 'If-Then' rules are constructed to combine the linguistic input subsets to the output fuzzy sets using the logical conjunction such as 'and'.

Application of fuzzy operator:- if the premise of a given rule has more than one part, then a fuzzy operator is applied to obtain one number that represents the result of the premises for that rule using 'AND' (min) or 'OR' (max).

Implication and aggregation:- implication is the application of the result of fuzzy operator on to output membership function and aggregation is the unification of the output of each rule by merely joining them. When the input value belongs to the intersection of the two membership functions, fuzzy rules corresponding to both the membership functions are invoked and the two output fuzzy sets are then unified to get one single output fuzzy set.

Defuzzification:-It is the conversion of a fuzzy quantity to a precise quantity. To obtain a 'single crisp' value, the resulted fuzzy set is defuzzified using the appropriate method such as 'centroid' evaluation, which returns the centre of the area under the curve.

1. System Description

The reservoir of Pamba Irrigation Project is impounded by Maniyar Barrage constructed across the river Kakkad, a tributary to the Holy river Pamba, Kerala State. The reservoir caters to the irrigation needs of 21135ha of land in Pathanamthitta and Alappuzha districts. The project was commissioned in the year 1979. The reservoir gets a perennial inflow from the tail race of Ullumkal-shep, which in turn gets inflow from the upstream Kakkad powerhouse of KSEB. Sabarigiri, the top most power house of KSEB, draws water from Pamba Basin formed by a number of reservoirs and after generation its tail race is gets collected and conveyed to the Kakkad powerhouse through penstocks. The reservoir has a catchment of 280 km², which is partially impounded by barrages as detailed below.

TABLE 1:Details of the cascade system

Sl. no.	Name of project	Installed capacity (MW)	Year of commissioning	water use at peak load (m ³ /sec.)	Average water use/unit generation (m ³)	Additional Catchment area(km ²)
1	KSEB- SABARIGIRI MOOZHIYAR- HEP	4X50+2x60=320	1966-67	55.11	0.62	
2	KSEB- KAKKKAD, SEETHATODE-HEP	2X25= 50	1999	45	3.25	28.75
3	EDCL- ULLUMKAL-SHEP	2x3.5= 7	2008	93	47	224
4	EDCL - AYYAPPA, KARIKKAYAM- SHEP	3x5= 15	2013	120	29	272.5

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

5	PAMBA IRRIGATION PROJECT-MANIYAR	Irrigation purpose.	1979	20	-	280
6	CUMI- MANIYAR- SHEP	3x4= 12	1994	100	30	

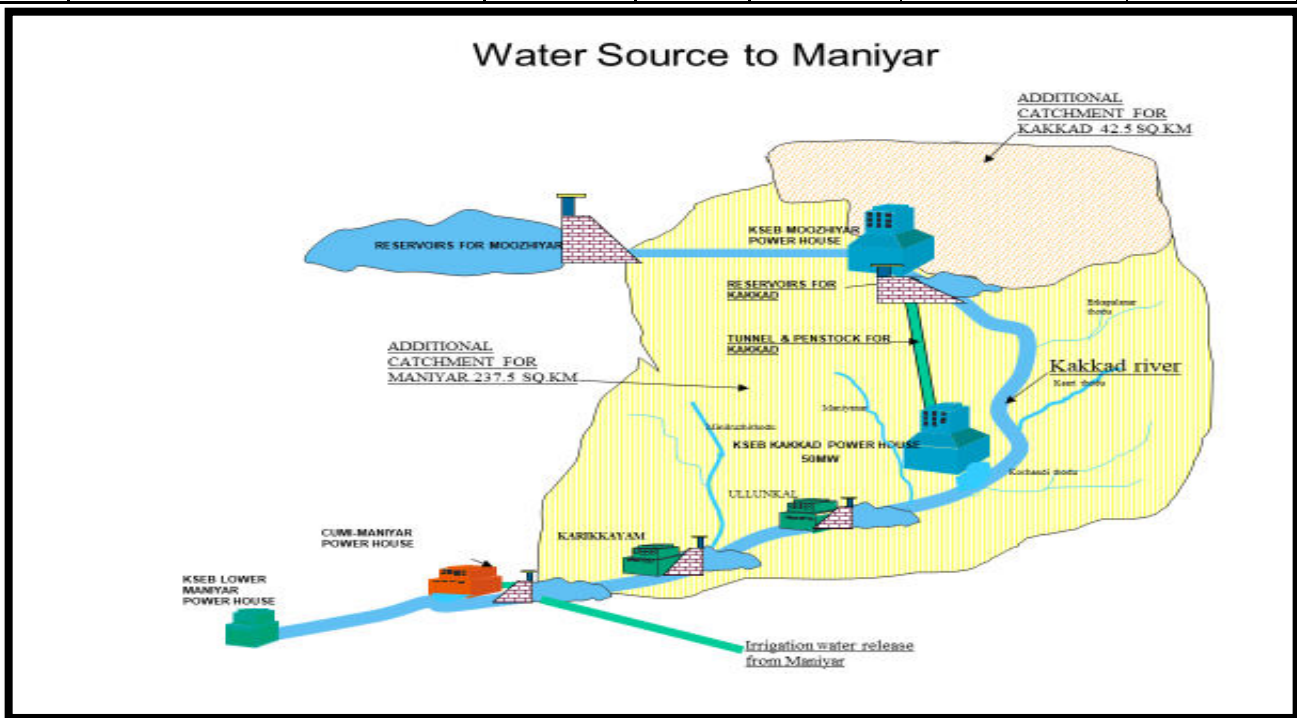


Fig. 1: water source to Pamba Irrigation Project, Maniyar Reservoir, Pathanamthitta Dt., Kerala State.

III. FORMULATION OF MODEL

Maniyar Barrage built across the river Kakkad for irrigation purpose forms the PIP reservoir and diverts water for the Project. The storage of the barrage is very limited and there is only an interim storage. The tailrace inflow to the reservoir varies as it depends on the State's power demand, but it is perennial. Runoff to the reservoir is intermittent as it depends on seasonal rains. In the present study a water year from June to May is divided to two seasons and two distinct set of rules are formulated. A month is divided to 3, 10 day periods and this results in 36 periods in a water year. The excess or shortage of days if any, is adjusted with the 3rd period of the month.

Season no.- 1- irrigation (dry) season:- irrigation demand starts in the month of November and ends by May, but during this period the inflow is less as it is contributed by the upstream tailrace alone. I.e, the prime purpose - irrigation demand- and the source- the tailrace inflow- are conflicting. Prime importance is to be given to irrigation supply and the surplus if any, may be used for power generation in this period. Out of the two demands- irrigation demand and power generation, irrigation is to be satisfied to its maximum degree during **Season-1** and power generation is to be planned to avoid spill/wastage of water.

Inputs

- Kakkad generation (ranges from 0-100 lakhs units)
- Irrigation water release (ranges from 0-55mcm)

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

outputs

- Power generation (ranges from 0-25 lakhs units)
- spillage from the reservoir (ranges from 0-50 mcm)

Membership functions are traced to 'low', 'medium', 'high' for input and output as detailed below.

	Input		Output	
	Kakkad-HEP Power generation (lakh units)	Irrigation water release (mcm)	CUMI-SHEP Power generation (lakh units)	spillageof the reservoir (mcm)
Low (L)	0-35	0-6	0-8.5	0-16
Medium (M)	25-65	4-11	6-16	14-31
High (H)	60-100	9-15	14-25	28-50

Table 2: range of variables- **Season1**- Irrigation Season

Rule No.	Input		Output	
	Tailrace Inflow	Irrigation	Power generation	Spillage
1	H	H	L	L
2	H	M	M	L
3	H	L	M	L
4	M	H	L	L
5	M	M	L	L
6	M	L	M	L
7	L	H	L	L
8	L	M	L	L
9	L	L	L	L

Table 3: fuzzy rules- **Season1**- Irrigation Season



Fig.2: generalised fuzzy rules

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

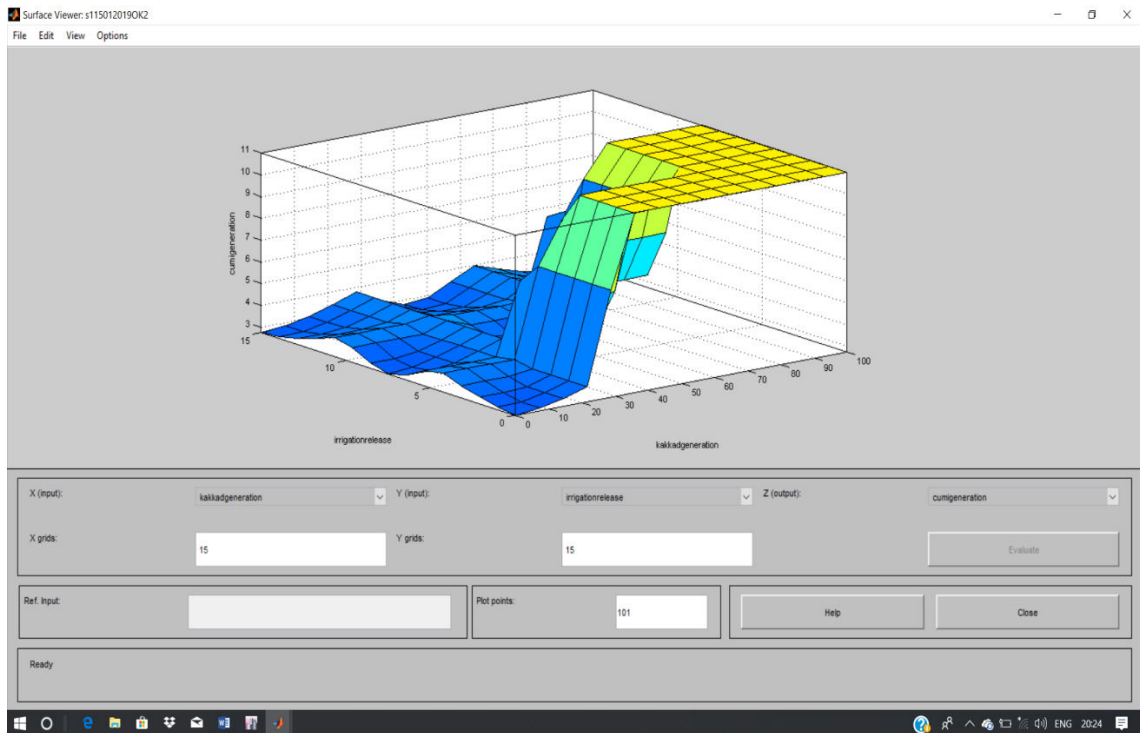


Fig.3: surface generated using fuzzy rules

Season no. 2 - non-irrigation (rainy) period:-the inflow to the reservoir is contributed by both the runoff and the tailrace and there is no irrigation requirement too. Thus the whole inflow can be used for power generation and there is occasional spill of water due to excessive rains. During **Season-2** , maximum power is to be generated to avoid spill/wastage as far as possible.

Inputs

- tailrace Inflow (ranges from 0-100 lakhsunits)
- Runoff inflow (ranges from 0-55mcm)

outputs

- Power generation (ranges from 0-25 lakhs units)
- spill from the reservoir (ranges from 0-50 mcm)

Knowing the storage, inflow (‘low,’ ‘medium’ and ‘high’) appropriate fuzzy rule is invoked. The fuzzy operator, implication and aggregation together yield a fuzzy set for drinking water supply, irrigation, power generation and spilling. A crisp release is then obtained using centroid of the fuzzy set.

Membership functions are traced to ‘low’, ‘medium’, ‘high’ for input and output as detailed below.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

	Input		Output	
	Kakkad-HEP Power generation (lakh units)	Runoff (mcm)	CUMI-SHEP Power generation (lakh units)	spillage of the reservoir (mcm)
Low	0-35	0-6	0-8.5	0-16
Medium	25-65	4-11	6-16	14-31
High	60-100	9-15	14-25	28-50

Table 4: Range of variables- **Season 2**- rainy season

Rule No.	Input		Output		Wt.
	Tailrace inflow	Runoff Inflow	Power generation	Barrage Spill	
1	H	H	H	M	5
2	H	M	H	L	21
3	H	L	M	L	12
4	M	H	H	L	1
5	M	M	M	L	5
6	M	L	M	L	9
7	L	H	M	L	
8	L	M	M	L	2
9	L	L	L	L	4

Table 5: fuzzy rules- **Season 2**- rainy season

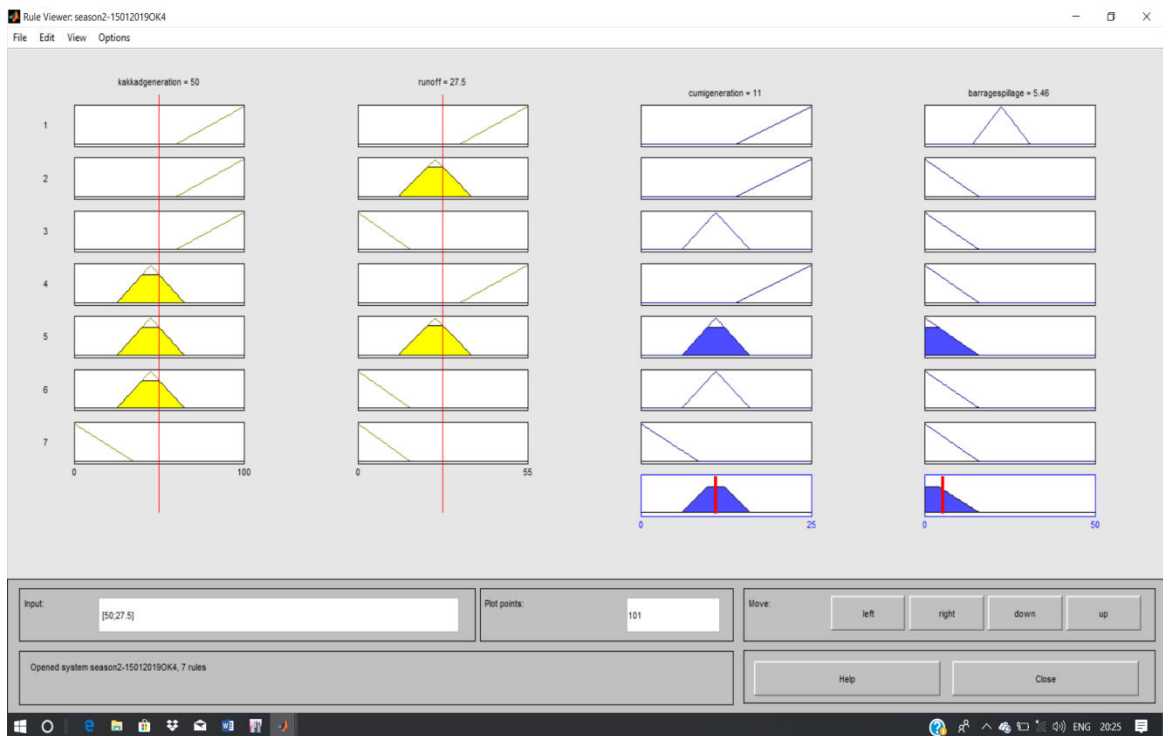


Fig.4: generalised fuzzy rules

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

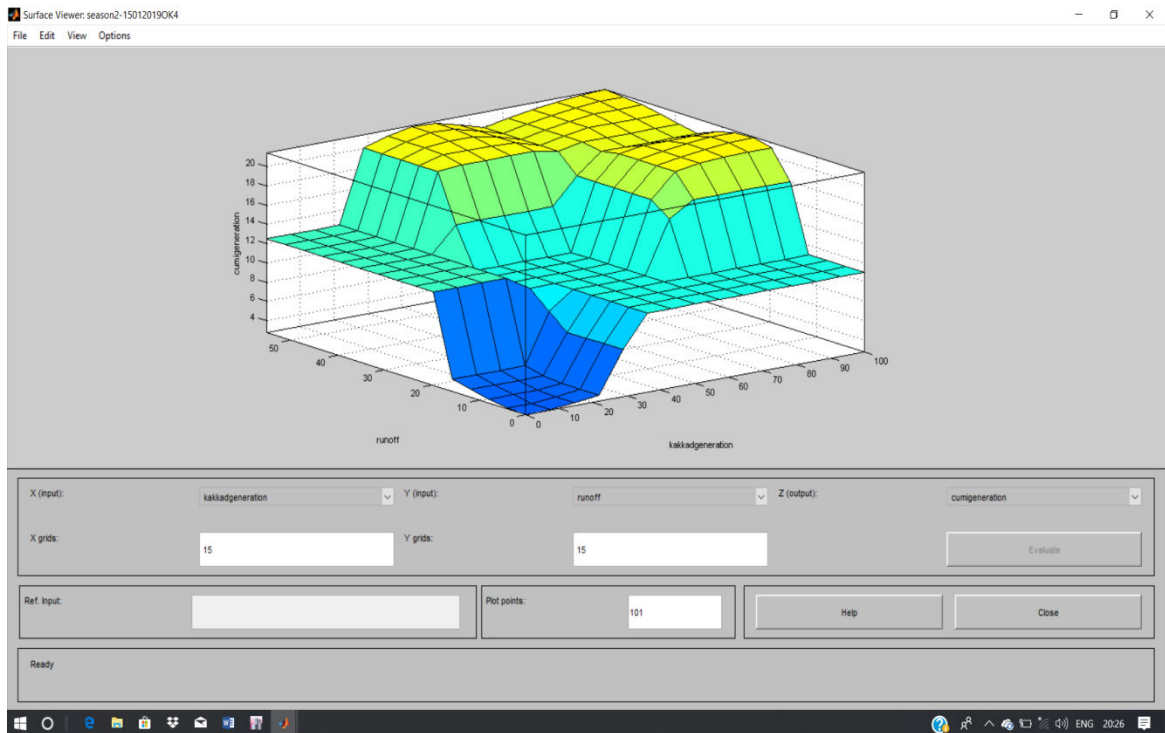


Fig.5: surface generated using fuzzy rules

IV. RESULTS AND DISCUSSION

As there is 03, 10 day periods in a month and irrigation extends from November to May, there are 21 periods in the season-S1 . The rainy season spans from June to October, there are 15, 10 day periods in season-S2. The Real and Fuzzy values of Secondary Generation at CUMI-SHEP is plotted against the 105, 10 day periods of S1 and 75, 10 day periods of S2 in two plots, for the five water years from 2009-10 to 2013-14 in in Fig.6 & Fig.7 respectively. It is obvious that the Trendlines go hand-in-hand.

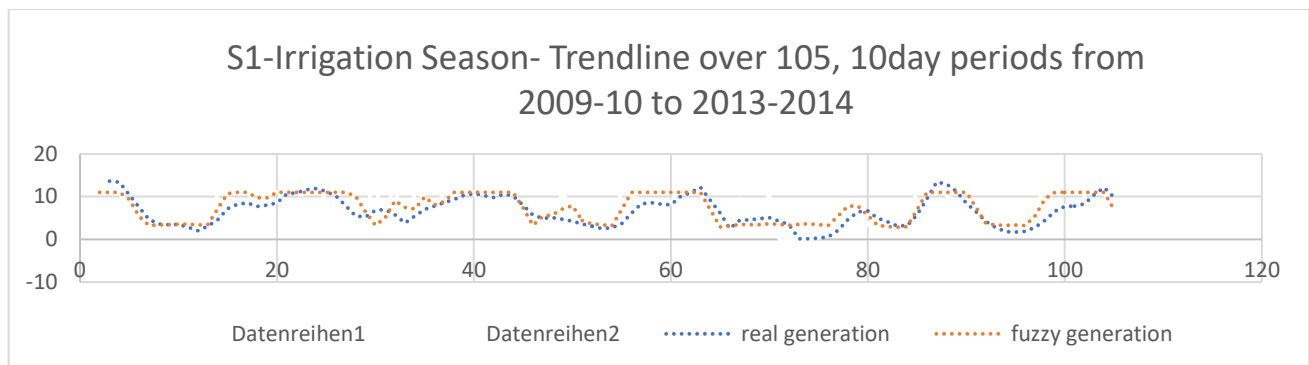


Fig.6: Comparison of Secondary Generation - Real and Fuzzy - during Irrigation Season

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

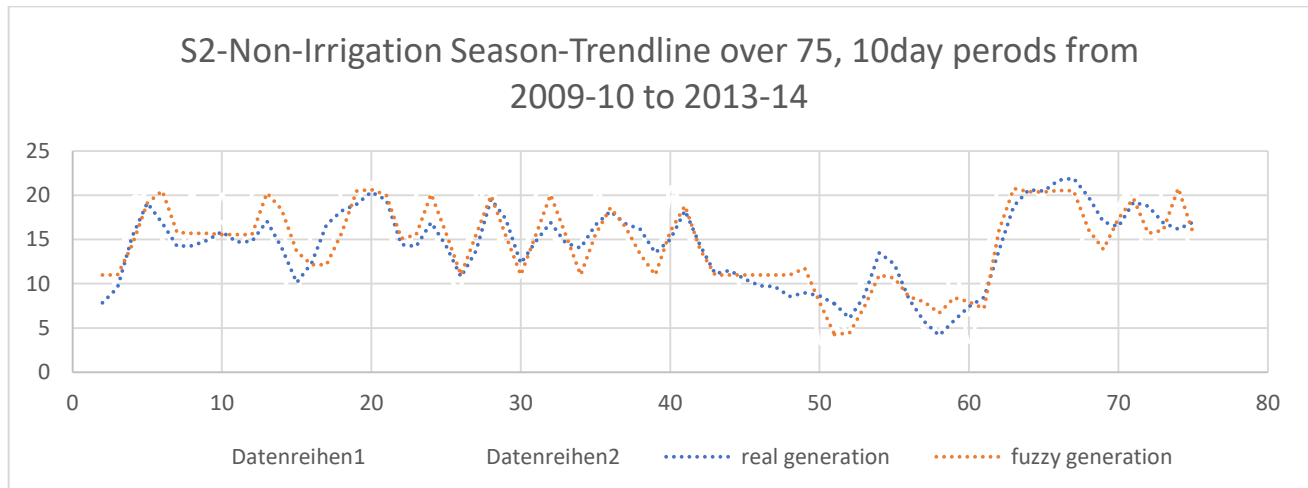


Fig.7: Comparison of Secondary Generation - Real and Fuzzy - during Non-Irrigation Season

In the present study FIS model for power generation is developed and demonstrated over an existing Irrigation reservoir impounded by Maniyar Barrage of Pamba Irrigation Project, Kerala State. The fuzzy inference system tool box available with the MATLAB software is used for developing the model. The inputs to the fuzzy system are Generation in units at the upstream HEP-Kakkad, Runoff and Irrigation demand on a 10 day period basis. The output is the Generation at the downstream CUMI-SHEP and the spillage at the Barrage. For the inputs and output operations, the logical and implication operators are taken as And method 'min', Or method 'max' and 'centroid' method for defuzzification. Where 'And' and 'Or' method corresponds to the conjunction (min) and disjunction (max) operation of classical logic. The results obtained shows that the values of secondary power generation at CUMI-SHEP, from the FRB model are satisfying the real time data. As the storage of a reservoir impounded by a barrage is very limited and highly fluctuating, that is not taken into account.

V. CONCLUSION

As the number of Membership functions for Input and Output increases, the error decreases. But as the number of Membership functions increase, the number of rules in the rule base also increase and lead to dimensionality problem. FRB models are seen highly useful for reservoir studies especially at the planning level.

REFERENCES

Books:

[1]. Timothy J Ross (*fuzzy logic with engineering applications*: Wiley:India Reprint -2014)

Journal Papers:

[2]. Panigrahi D.P. and Mujumdar P.P. (2000), 'RESERVOIR OPERATION MODELLING WITH FUZZY LOGIC' Water Resources Management, 14 P 89-109.

[3]. M. Abbas, M. Saleem Khan, Nasir Ali (2011) Fuzzy Logic Based Hydro-Electric Power Dam Control System, International Journal of Scientific & Engineering Research Volume 2, Issue 6, June- 1 ISSN 2229-5518

[4]. R. U. Kamodkar, and D. G. Regulwar (2013), Multipurpose Reservoir Operating Policies: A Fully Fuzzy Linear Programming Approach, J. Agr. Sci. Tech. Vol. 15: 1261-1274

[5]. Umamaheswari G.R., Kalamani, (2014), Fuzzy logic model for the prediction of ground water level in Amaravathi river minor basin, International journal of mathematics trends and technology vol. 11(1), P 46-50.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 1, January 2020

- [6]. Suryanarayana T.M.V., Mihir Kemkar(2014), 'Fuzzy rule based model for optimal reservoir release', International Journal of Modern Engineering Research, 4(6) P 29-32.
- [7]. PranitanBalve, Jayanlal N Patel (2016), 'Optimal reservoir operation policy using fuzzy linear programming', International journal of advances in mechanical and civil engineering, 3(4)p 77-80

BIOGRAPHY



P.S. KOSHY completed his B.Tech. degree in Civil Engineering from Mahathma Gandhi University, Kerala with Second Rank in the year 1994. He completed his M.Tech. degree in Structural Engineering and Construction Management and presently working as Executive Engineer, Major Irrigation Division, Ernakulam in Kerala State Irrigation Department. He has been working as an Irrigation Engineer for the past 21 years and he has a good track record in managing multipurpose Irrigation Dams/Barrages, Irrigation water distribution, canal construction and maintenance. Apart from this, he published many technical papers in national and international journals.



Dr. G. PRINCE ARULRAJ obtained his B.E. degree in Civil Engineering from Thiyagarajar College of Engineering, Madurai in the year 1982. He secured First Rank in the College and Second Rank in Madurai Kamaraj University. He got his M.Tech degree in Civil Engineering from IIT Madras in the year 1984. He got his Ph.D. degree from IIT Madras in the year 1999. He has 35 years of teaching and research experience. His fields of interest are Water resources engineering, Applications of GIS, Concrete with nanomaterials and Fire resistance of concrete.



DR. J. BREMA has an academic background with B.Tech in Civil Engineering, Postgraduate degree in Water Resources and Doctoral degree in Civil Engineering (Specialization in Water Resources). Apart from teaching, she has carried out research work and have published more than 90 research papers in national and international journals and conferences. Currently she is guiding 6 doctoral students and has fellowship in Institution of Engineers, membership in Indian Society of Technical education and Indian Water Resources Society. She has published a book on Precipitation Variation with reference to Land use change- Noyyal Basin, Lambert Academic Publishing in the year 2017.