e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:11/November -2020 Impact Factor- 5.354 www.irjmets.com

REVIEW OF RESERVOIR OPERATION MANAGEMENT BY FUZZY LOGIC

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ABSTRACT

In this article, review of fuzzy rule based model for the operation of a single purpose reservoir is made. The fuzzy model is largely depends on the input and output values of the premises. The fuzzy model normally consists of forming membership function for the input and output values, formation of rule base, implication and defuzzification.

Keywords: Fuzzy, Fuzzy Logic, Reservoir management, water resource system

I. INTRODUCTION

Water is the greatest resource of earth. It makes life comfortable and luxurious along with survival. Beside various other uses of water the largest use of water in the world is made for irrigating lands.

After independence, India has been made irrigation potential up to 113.53 Mha in 2012 from 22.60 Mha in 1951; despite this achievement however we have utilized only 87.60 Mha during 2011-12. And this triggers the need to make definite policies to achieve the maximum irrigation potential and also to improve crop intensity.

Although irrigation facilities are very important and much needed for the development of nation, they are complex. Proper development of water resources involves the most economical utilization of the entire available water of a country to meet the needs of its various regions, such optimum development of water resources must also give due consideration to ecological aspects by proper allocation of low river flows foe environmental consideration, rather than diverting them entirely for irrigation demands this make this field very complex and needs definite policy to ensure maximum benefit.

The real time reservoir operation consists of continuous decision making on water levels, available inflow, demand, and release. It contains uncertainty in operations because the dependent variable may change according to time. The task of operator is to fulfill the objective as the input variables are time dependent & the decision making becomes complex.

In India the inflow may change with season & the season does not start on the same date every year therefore the fuzzy logy is a very important tool in real time reservoir operation. As in India the objective consist of irrigation planning & the demand of water and corresponding availability of water changes with season to season therefore it is necessary to have flexible tool in management of reservoir operation instead of relying on traditional methods.

Reservoir operations are the real time operation as it requires simultaneous decision making depending on water availability in reservoir and discharge require according to seasonal requirement. The decisions made in system are always entangled with operating policy and strategic planning. The real time operation are important in concern with complexity of the release decision as release is depends upon time dependent information. In this all the task of operator is to make sure that objectives are fulfilled with respect to the legal and other constraint. As denoted above the reservoir release decisions entangle with uncertainty, which come in to sense when objective changes with time, and conditions of climate and also time of year. To get the objectives in definite values is often comprise of complexity. To predict the inflow into the reservoir along with water level when there is seasonal variation and there is no chance that the season will start every year on same date it brings uncertainty in operation system, and hence the fuzzy logy can provide the most appropriate solution to that by providing reservoir operation model.

In India as the irrigation projects are planned by considering many objectives and although they are entangled with high range of variables it is necessary in India like nation to have efficient study and research on the sustainable strategies and objective framework with fuzzy logic to have practical policy on reservoir operation management.

As the fuzzy logic approach towards the reservoir operation system is more and more flexible and it involves expert opinion within whenever needed it can be provide a most relevant approach to the reservoir operation and it will be a most prominent alternative for present method, which allow operator to involve in making policy.

The fuzzy control method is advantageous as it can control the process that most complicated in behavior and difficult to be mathematically modeled. In fuzzy logic the membership function associated with the data and rule base made on the expert knowledge play an important role therefore it is require to determine the membership values precisely.

II. FUZZY RESERVOIR OPERATION MODEL

The main task with which the reservoir management entangled is to control the system that operates the spillway gate in a dam to increase or decrease the amount of supply of water. It is a most important task of system to maintain the water level in reservoir in range needed for fulfillment of objectives associated with project. This is done to maximize the benefits associated with fulfillment of objectives of irrigation project. To determine the inflow in a reservoir is difficult due to hydrological conditions in India. Added to this unpredicted consequences may occur which can result in uncertainty. And it can make difficult to make the effective reservoir operation system. There is no doubt that every control system designed is to maintain the water level in the range where it can maximize benefits associated with fulfillment of objectives of project. Water resource planning and effective management of reservoir is an important area for the optimal uses of water stored in the reservoir to satisfy different economic groups related with the project. It is necessary to make efficient and effective use of water in reservoir scientifically which are complex in nature.

In India as the water availability is mainly depends upon the seasonal rain the inflows associated, & storage for reservoir are changes with season also the demand of water largely depends upon the crop sown in command area and also on climatic conditions in particular time period therefore allocation of water becomes complex problem. Therefore it is needed to evaluate the current operating rules for existing water supply structure and also to form new rules according to need of the objectives of the water resource system.

In fuzzy logic model gets wise input data and then form this data into fuzzy sets that elaborate the function of related input data. This is known as fuzzification. Then the fuzzy rules inputs inference to outputs during the inference phase. At last in the defuzzification the fuzzy outputs map to the wise output variables.

It has been noticed in several researches that fuzzy based system is a universal approximators. These proofs stem from the isomorphism between two algebras- an abstract algebra and a linear algebra and the structure of fuzzy system, which comprises an implication between actions and conclusions. The reason for this isomorphism is that both entities involve a mapping between elements of two or more domain. Just as an algebraic function maps an input variable to output variable, a fuzzy system maps an input group to output group, in the latter these groups can be linguistic proposition or other forms of fuzzy information. The foundation on which fuzzy system theory rests is a fundamental theorem from real analysis in algebra known as stone-weierstrass theorem.

Fuzzy system can work in following way.

1. Fuzzification of Input and output data available using appropriates terms such as high, medium, low, etc.
2. Based on DP or expert opinion and available information, fuzzy rules constructed to comprise the appropriate inputs sets to the output fuzzy sets using the conjunction such as “and”.
3. The shape of the consequent based on the premise (antecedent) part of fuzzy system is defined as the implication.
4. At the last the defuzzification of the fuzzy set to have a crisp value is done by the method of centroid.

In fuzzy modeling for reservoir operation the subjectivity which exists in modeling we can treat this as blessing rather than drawback. The lack of clarity present in the definition of terms is consistent with the information contained in the conditional rules developed by the engineer when observing some complicated

process. Most useful linguistic terms we get from Fuzzy mathematical tools and the calculus of IF-THEN rules which can be used for the automation and implementation of an extensive body of human knowledge heretofore not embodied in the quantitative modeling process; we call this paradigm fuzzy system. For exchange of human knowledge in means of communicating and transferring these mathematical tools can be useful.

While formulating the important policies regarding to planning, design, operation of the water resource system the operator should keep eye on proper regulation of water resource system. As each water resource system is entangled with his own environment system and also have unique eco-social system it comprise of its own type of data collection, and management system to prepare and execute the most suited operational plan. There are lot of researcher have done measurable work in defining the outcomes associated with water resource system and to regulate it by using fuzzy logic and each one is unique. The fuzzy set is mainly consist of formation of framework for representation of conceptual data and can be used in many ways in real life problems. The any water resource system entangled with a load of data which then make a great need to proper analysis of data to take any decision regarding the management of water resource system. The data collected in the concern with any unique water resource system should be reliable as the any decision which made is depend on the data available to operator and the outcomes associated with the water resource system are also associated with the decision made by the system management and will affect the stakeholders also.

At the time of regulating the reservoir system any operator should keep an eye on the reducing the difference between benefits associated with supply of water and demand of water in command area as supply overpassing the demand is unnecessary and can affect the objective of the reservoir system. Although the task is complicated as the demand can be relied on the number of things present in environment of command area but with sound and reliable data about the characteristics of the command area operator can achieve the objective associated with the reservoir system. While developing the proper reservoir operation system it is not enough to keep an eye on only to fulfill the interest of the stakeholder but the operator should also keep an eye on variability of water inflow, rainfall etc. considering this many of researcher refer the use of fuzzy logic to overcome the uncertainty associated with reservoir operation management.

The eco-social system associated with the water resource system can define the need of fuzzy set require. As any reservoir system consist of large number of data the membership function with multiple degrees can be used to represent the infinite values within and can be result in key for decision making. Fuzzy logic can be used as an important tool in reservoir management system based on the set of the rule relied on the eco-social factor.

To solve the complexity of the reservoir system there are lot of techniques available in world which include evidence theory, imprecise probabilities theory but as per the research done by Panigrahi and Mujumdar (2000) the fuzzy set theory can express uncertainty and ambiguity of storage of reservoir at different time period, inflow and release effectively. In the extensive research of most of the researcher they have divided annual flow of reservoir system in different time period according to need of objective of the respective resource system. When the modeling is based on the past data it is difficult to use nonlinear mathematical approach for the complicated system like reservoir. In turn, fuzzy based analysis can be used as a tool for modeling of water related problems for varied field applications as discussed in the literature review. The application of fuzzy system can be entangled with the identification of the possible inputs and outputs for the system then to form the definite terms for the possible premise and consequences associated with resource system, forming membership for each depending on experimental analysis or on the basis of expert opinion, forming the sets of possible occurrences and outcomes associated with that. The degree of membership functions can be derived using various techniques available in the literature such as inductive reasoning, entropy minimization screening method, batch least square algorithm, gradient methods, learning from examples and previous studies.

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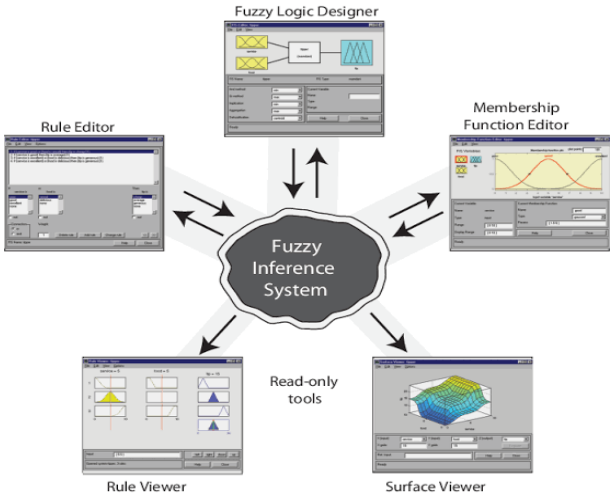

Figure 2.1 : Fuzzy Inference System

2.1. Fuzzification of the Inputs

To define the degree to which the input associated to each wise fuzzy set by membership function is a really first step in developing the fuzzy inference system for reservoir operation management. In fuzzification the input which is a numerical value we get from past data is converted in membership function normally within 0 to 1. The problem faced in fuzzification is as the terms are represented in subjective manner and one should capture the meaning of them and assign them to the degree of membership function. Generally the construction of membership function can be done in following ways. The construction of membership function entangles a specific knowledge, expert opinion, and knowledge engineer which elaborate the knowledge of interest from the experts and to apply this knowledge to required operational form. The operator tries to elaborate knowledge in natural language and then try to determine the meaning of each term. The construction of membership function can be done in two ways as direct method and indirect methods which is based on expert judgment.

Direct method: - In direct method the clear and definite answers are given by expert to various questions asked for the development of membership function.

Indirect method: - Experts are expected to answer simpler questions, easier to answer and less sensitive to various sequences which are useful for the development of membership function only implicitly. Both the methods entangle one or more experts.

Determining membership functions has been one of the essential research pursuits in fuzzy set simplicating the developments of their fundamentals and supporting a realization of applied aspects. Depending upon the particular view of membership functions one focuses on, we can distinguish between two main classes of methods considered in the problems of membership function estimation, namely: 1) Expert-driven approaches: In this approach the membership function derived with the help of expert knowledge. 2) Data-driven approaches: In this approach the membership derived from the collection of past data and by analyzing it. Membership function can comprise the all data in fuzzy set hence it is necessary to have lexicon of terms to develop and derive features of the function.

The region of the universe which corresponds to complete and full membership function can be defined as the core of membership function for some fuzzy set A.

That is, the core comprises those element x of the universe such that $\mu_A(x) = 1$. [I]

While the supports of MF can be defined as the region of universe of set A characterized as non-zero MF for set A. That is, the support comprises those elements x of the universe such that. [I]

$\mu_A(x) \geq 0$.

The boundaries of a membership function for some fuzzy set A may be denoted as that region of the universe containing elements that have a non-zero MF but not complete membership. The fig. shown below describe the parts of MF such as core, support, boundries.

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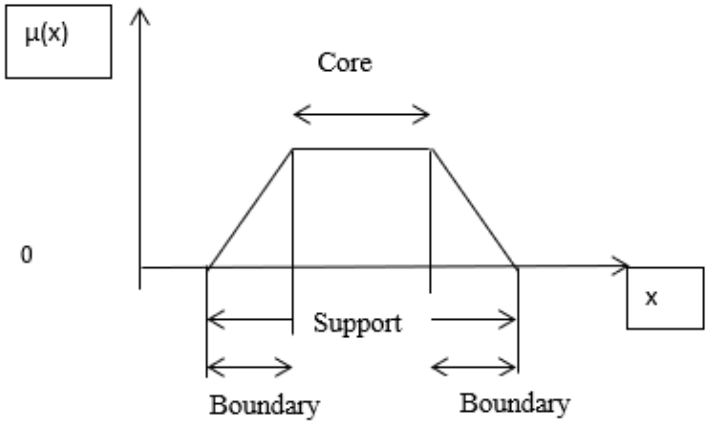

Fig. 2.2 Membership function

At first as above mentioned it is necessary to determine the degree for the crisp input x entangle with the respective sets. Meanwhile the mapping of crisp input in to fuzzy set is known as fuzzification. The different types of fuzzifier available for fuzzification are Gaussian fuzzifier, singletone, and trapezoidal fuzzifier.

In case of Boolean logic or any other method the membership function is either belong to 0 or 1, that means the answer is either it belongs to the set or not either it characteristics value is 1 if it belongs to specific object and 0 if it does not belongs to the specific object. But with fuzzy logic it is necessary to find the degree to which it is belong to the characteristic value of specific object or not and it gives membership function ranges from 0 to 1 according to blondness of the class.

Membership function can be symmetrical or asymmetrical. The MF can be derived on multidimensional universe but they are generally derived on one dimensional universe.

2.2. Formulation of the Fuzzy Rule Set

While the formulating the rule base for a particular reservoir system it is required to take help of expert knowledge regarding the particular reservoir. Fuzzy rules for any reservoir system are formulated on the basis of expert knowledge. We can derive the fuzzy rule in the form of: If the storage is high, and the inflow is high, then release is high.

After fuzzification of the input data we get membership values which in next step we apply to the antecedents of fuzzy rules. In case the fuzzy rule carry multiple antecedents to have a single number which represent the antecedents we have to use fuzzy operator.

The transition for an element in the universe between membership and non-membership in a given set is abrupt and well defined in classical or crisp sets. The transition can be gradual for the universe of fuzzy set. As we saw in previous sections the boundaries of the fuzzy sets are vague and ambiguous and it can be confirmed by the transition among the various degrees of membership. And hence the membership of an element in this set is measured by a function that attempts to denote vagueness and ambiguity. And this can result in elements in any set have various degrees of membership and can be a member of any other set in the same universe.

For the development of conceptual framework the concept of a fuzzy set provide a convenient point of departure which is same as the framework developed in case of any ordinary sets, but it have a wider scope of application. Although there are lot of ways to represent the human knowledge but it is necessary to denote it in simple and common way in to the natural language in the field of artificial intelligence

IF (antecedent), THEN conclusion (consequent).

The form in expression is commonly referred to as the IF-THEN rule based form this form is generally referred to as the deductive form. It typically expresses an inference such that if we know a fact then we can infer, or derive, another fact called conclusion. This form of knowledge representation, characterized as shallow knowledge, is quite appropriate in the context of linguistics because it expresses human empirical knowledge in our own language of communication.

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2.3. Application of Fuzzy Operator

After fuzzification of inputs we come to know about the fact of the degree to which each rule is satisfied. As we discuss in previous sections if premise have more than one part then to obtain the one number which represents premise of the rule fuzzy operator is applied. It is possible that the input from premises of rule are two or more to the fuzzy operator but the output we get is single truth value. Where the AND operator may be the product of two parameter entangled with or it can be conjunction (min). Similarly the OR method may be probabilistic or it can be disjunction (max).

The probabilistic OR method is defined by the equation.

Consider an example that we have storage and inflow for some time period in year which we can denote as input 1 & input 2 respectively. Both the inputs we have will be the part of the rule.

if storage is 0.4 or inflow is 0.8 then ...

(m, n) = m + n − mn……..(1)

Consider the two different parts of the premise yielded the membership values of 0.4 and 0.8 for storage and inflow, respectively. And to obtain the single number that belongs to the result of the premise apply fuzzy operator in this case the fuzzy OR operator simply selects the maximum of the two values, and the fuzzy operation for the rule is complete. If the rule uses the fuzzy probabilistic OR (probor) operator then the result will be calculated by Equation (1), where m and n correspond to the membership values of both the inputs. In this case, the result of the probor operator works out to be 0.88.

2.4. Implication

As we know from the above section the fuzzy operator is apply to have a single value which belongs to the inputs in the premise if input consists of more than two premises. After the application of fuzzy operator and getting a single value next step is to obtain the fuzzy set for the rule by applying the result we get from fuzzy operator to the output membership function. This is done by the implication method. Obviously as we discussed above a single number resulting from the premise is the input for the implication method, and the result of implication is a fuzzy set.

2.5. Aggregation

As aggregation is the process of merely joining of output of each rule we can say aggregation as a process of unification of output from premises. If the input value entangle with the intersection of the two membership function, the fuzzy rules related to both the membership functions are invoked. After implication each of these rules specifies one output fuzzy set. Again if there are two output fuzzy sets are available then fuzzy sets are unified to get one single output fuzzy set. If more than one input lies in the intersection regions, all corresponding rules are invoked and aggregation is carried out on the output fuzzy sets. Aggregation occurs once for each variable. The input of the aggregation process is the list of truncated output function returned by the implication process of each rule. The aggregation process always gives one fuzzy set for each output variable. The aggregation methods are entangled with: max (maximum), probor (probabilistic or), and sum (sum of each rules output).

From the above discussion we can say that fuzzy rules often provide fuzzy information about the same variable and different outputs must be combined. Unification of the outputs of all fuzzy rules is known as aggregation. That is, aggregation takes membership function of all rules consequents and combines them in to a single fuzzy set. For implementation of aggregation Fuzzy set operations, such as union and intersection, can be used.

Most rule based system involves more than one rule. In aggregation of the rule the single value for the different rule base of the consequents is obtained.

In determining an aggregation strategy, two simple extreme cases exist. [I]

1. Conjunctive system of rules: - In the case of system of rules that must be jointly satisfied, the rules are connected by AND connective. In this case, the aggregated output is found by the fuzzy intersection of all individual rule consequents. [I]
2. Disjunctive system of rules: - For the system of a disjunctive system of rules where the satisfaction of at least one rule is required, the rules are connected by the OR connectives. In this case, the aggregated output is found by the fuzzy union of all individual rule contribution.

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2.6. Defuzzification

As we come to know now that the result obtained from process here now is in the form of a fuzzy set. And if we want to apply result this should be defuzzified. The fuzzy set is an input for the defuzzification process and the result we get from defuzzification of fuzzy set is single crisp number. As we know the centroid evaluation is the most common defuzzification method, which returns the center of area under the curve.

As we cannot order the system that release water very low, medium or high we have to convert these linguistic term in to specific amount and that is why the process called defuzzification is important. With defuzzification we can solve complicated problems with analogous form of defuzzification in mathematics and find the real and imaginary parts of the solution and then de-complexify the imaginary solution back to the real space. Meanwhile we can say defuzzification is natural and necessary process in fuzzy system.

The probabilistic method of maximum likelihood can be used to derive the defuzzification methods of maximum membership like largest of maximum (LOM), middle of maximum (MOM) or smallest of maximum (SOM).

III. RESULT

Because of the subjective judgment regarding reservoir system and thumb rules associated due to uniqueness of each design problem are unavoidable the uncertainty we discussed in above all sections concerning with application of the knowledge to actual reservoir system model still remain as it is. This is why reservoir managers are comfortable with fuzzy set theory. As the standards of safety demanded by general public regarding the allocation of water carry an extreme importance with self. The skill of designer while dealing with uncertainty is crucial. The planner has to make the decisions along with the uncertainty entangled with system, and the complexities, vagueness and ambiguity associated with system can trigger the use of fuzzy concept for reservoir operation modeling. For satisfaction of socio-economic factors regarding release and for the comfort of the operator the fuzzy logic model based on MATLAB is very most suited.

IV. CONCLUSION

Fuzzy system model developed in this research use past data of dam itself in order to get the knowledge base to formulate the fuzzy rule. The use of past data and transferring them to the fuzzy rules result in effective participation of local authorities, which result in enhanced and best utilization of water resources. The objectives associated with reservoir system can be best achieved by the fuzzy system.

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