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Development of a Multipurpose Water Reuse and Power Production System

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ABSTRACT: In today's world renewable energy is highly demanding because of increasing oil and fuel prices, desire and necessity to avert irreversible climate damage and also the unreliability of the non -renewable sources. In renewable energy, water is an important source. Previously water is used only for survival of human being as much as food but no attentionhas been givenen to economical use and conservation of resource for domestic power generation through roof top rain water harvesting. In the modern times, this rain water serves for several purposes. Beside the production of hydel power, it is also used in crop cultivation, fishing and as well as for drinking purpose. Without doing this as a single work, we try to merge several works done. In such a way, there will be a chance of increasing utilization of rain water harvesting.

Keywords: *ANN-GMDH Model; DE and GSO optimization; Scenario Analysis*

INTRODUCTION

Sustainable empowerment of human population can only to be place if three basic resources: water, food & energy is aptly available and ideally utilized. But in most countries in the world due to the lack of distribution & monitoring the basic resources are mis-utilized. This resulted in scarcity for the water, energy & food. Along with growing population density one of the major reason for the uncertainty can be attributed to non-optimal utilization of the resources. The next section tries to highlight this point with latest literatures and also discusses about the possible situations available in this regard.

Water scarcity

Water is one of the important resources for the sustainability of human being. Uncontrolled increment of the population density increased the demand of water. Uneven distribution of water & also inevitability can't mitigate these demands. Due to this every region of the world was affected by water scarcity. Nearly three-fourth of the India's population lives in water stressed region (per capita availability less than 2000 cubic metre) and the other one –third region is in water scare area (per capita availability is less than 1000 cubic metre) (Keller *et al.,* 200).

Gurung and Sharma (2014) has stressed on the necessity of reliable alternative water supply source to compensate the demand of water created from the rapidly increasing population density (Gurung, and Sharma 2014).

The water scarcity problem in semi-arid region can be mitigated by the implementation of traditional rain dependent supply sources (Bouma *et al.*, 2007) and reuse of water (Furumai 2008) are seem to be more reliable.

Water reuse

Water reuse is defined as the use of reclaimed water for a direct beneficial purpose. In many places now,

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water is reused for water conservation after using it for intended purpose (Nair and Ahammed 2013; Simons *et al.,* 2015).

In china, wastewater reuse is an efficient way and a key consideration of water policy making (chu *et al*. 2004).This water reuse policy is very much effective in global market. Rather than china in Europe and many other countries where the fresh water scarcity has enforced to water security (Bixio *et al*, 2006).

Water reuse system has a significant potential for further development according to analysts. Overall estimation predicts that water reuse volume may reach 3222Mm^3/year in Europe by 2025 with Spain it shows the greatest potential of Water reuses (BEXLEY'S CORE, 2009).

Rain Water Harvesting

Many states of India has started to use the rain water for numerous purpose (Abraham *et al*., 2014).

The report of Centre for Science and Environment, Delhi published in 2009 has clearly stated that RWH could supply the 26 gallons of water per persons in future.

Energy Scarcity

The increase in population density and their demand for luxury along with the rapid development in technology after the industrial revolution has greatly increased the use of fossil fuel from the end of 20th century and is still increasing. Equalizing the pace at which global population density is incrementing. "The consumption rate in 2011" has increased approximately 8156 million tonnes of oil in 1991 to 12, 274.6 million tonnes. At the current production rate scenario oil will last for 54.2 years (BP.2012), only.

In the global scenario around 1.3 billion populations from the remote areas, unable to access the electrical energy due to several problems (Bhandari *et al*., 2014). In India, 70% of the population lives in the villages or remote areas that are not directly connected to the national electricity grid. The consumption rate of coal has increases to 744.519 million tonnes from 720.346 million tonnes in the year 2014 (W. E. Council, 2050).

Currently the scarcity of energy supply is mitigated with the help of renewable energy sources like solar, hydro etc and also the recycling the energy (McKenna *et al*., 2013). In the last decade's 11% of energy demand was satisfied from different energy sources and the share is supposed to increase upto 60% in the year 2070 (Hossain *et al.,* 2007).

Renewable energy system

The increasing manner of the electricity demand does not satisfied by the high power generation station. A method to fill out the gap of the energy demand is using alternative energy sources like micro hydro power, wind power, solar system etc. The term "renewable" is generally applied to those energy resources and technologies whose common characteristic is that they are naturally replenish able (Boyle 2004).

Renewable energy technologies produce power, heat or mechanical energy by converting those resources either to electricity or to motive power. Such commercial technologies include hydroelectric power, solar energy, fuels derived from biomass, wind energy and geothermal energy.

Energy Reuse System

One of the most important pillars in the transition towards a sustainable energy system is energy efficiency. Energy productivity can be increased by the reuse and recycling of energy. Direct secondary reuse (DSR) is defined here as the reuse of a energy at the end of its use phase without destruction of the existing product design, and is divided into direct reuse (McKenna *et al*., 2013).

Food security

The assessment of risk due to water scarcity is not limited to the "demand and supply" problem of fresh and drinking water. Limited amount of freshwater will also hamper the agricultural sector (Gain and Giupponi 2015). The Literature review says that there is a dramatic increase in the demand for food because of global population density will increases by 2.25 billion people from today's level and will reach 9.15 billion by 2050 (Despommier 2010). For a low- and middle- income countries agricultural output annually increased to 60% to 70%. But the quality of land has remained unchanged. In fact according to the report of Food and agriculture organization the arable land per human being may reduce by 0.20 hectare in 2020, compared to 0.45 hectare in 1965 (Hertel 2011). Also the land erosion problem is a big issue which may reduce the area of cultivated land (Geman and Eleuterio 2013). The food demand of the world can be somehow supplemented by use of the vertical irrigation system (Banerjee and Adenaeuer 2014).

Vertical Irrigation system

The vertical farming technique was approached by the Scientist Despommier to solve the food scarcity problem of 21st century. The original high rise farm was invented by him. This multi storey farming system could also solve the energy and transportation cost. It reduces the greenhouses gas emissions too. Another advantage is that land which is used for agriculture could be returned to nature-vital ecosystems such as forests, which stored CO_2, thereby removing it from the atmosphere in that way.

According to the Professor Despommier, this vertical irrigation system which will be farm in a 30-stored building might able to supply food to 50,000 in the near future.

There are many rain water harvesting, water reuse and renewable energy schemes installed all over the world. But each of them is used separately. None of them are ever used in a combined way. But there are certain benefits if the individual solutions are used in combined manner. Table 1 depicts a comparison between the solutions used combinedly and separately.

From the Table 1 which is based on literature survey is clearly seen that the single system like water production system, food production system and Energy generation system costing is high but the efficiency is low comparison with combined system. The optimization result shows that the combined system costing is approximately Rs.20000/- and overall efficiency is 95% (approx). This table shows the convenience of combined system over single system.

Objective of the present study

The objective was to develop a system which can reuse rain water in production of power, food and portable water. The optimal dimension and specification of the system was estimated as the Nature based optimization method. In total three designs were developed from the results of the optimization. The performance analysis of the three systems was carried out through three different climatic scenarios. The design which performance more optimally then the other was selected for real life applications.

Brief Methodology
Flowchart

Glowworm swarm optimization and Differential Evaluation

Glowworm swarm optimization (GSO) and Differential Evaluation (DE) technology are used to find the optimal design specifications for yielding maximum energy, water and crop efficiency under minimum expenditure.

Identifications of Optimal Design specification

Three optimal design specifications have got by comparing the result of GSO optimization technique and DE technique.

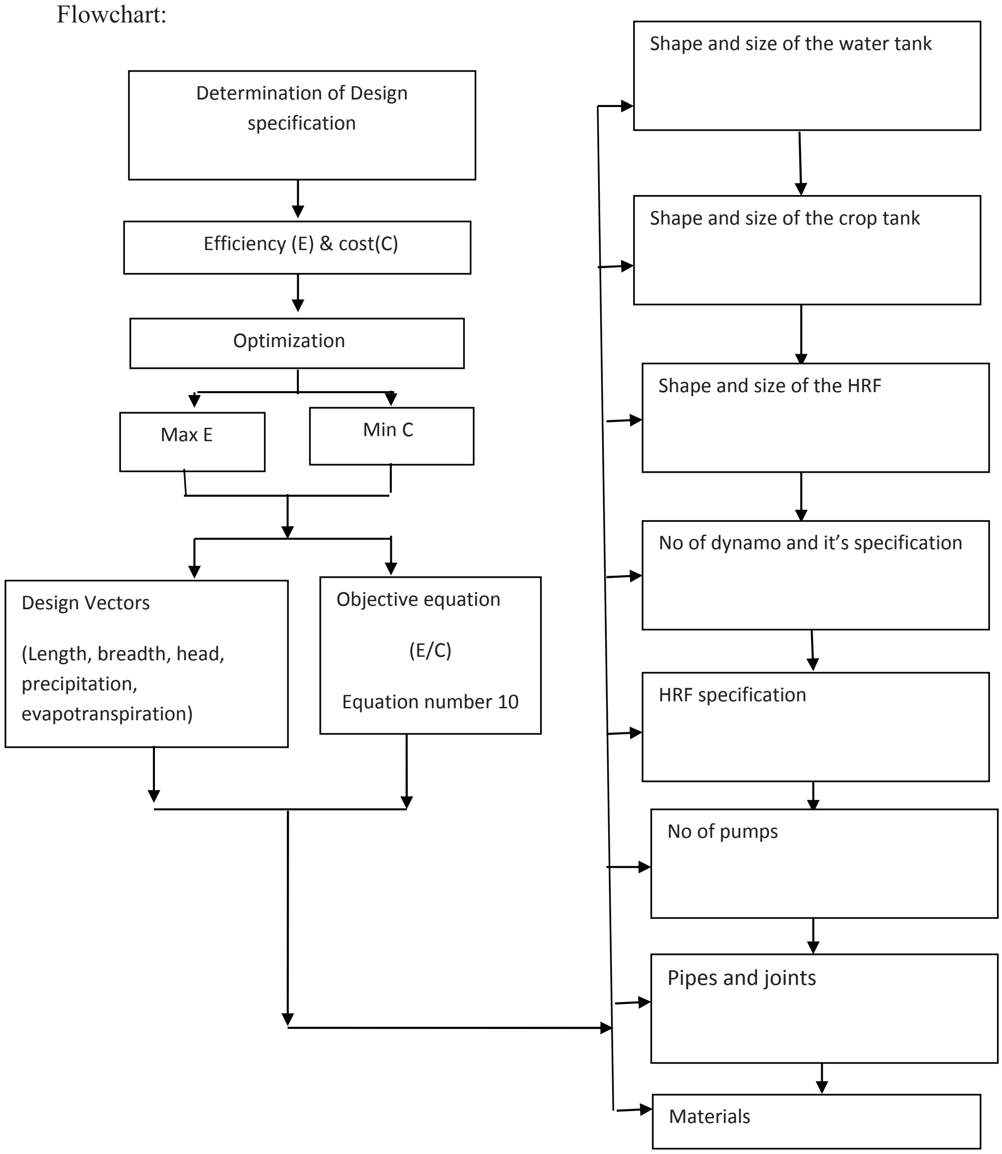
Performance analysis of the model

The performance analyses of the three optimized design specifications are done by the help of the ANN-

Table 1: Sharing the production of energy, food and water separately and combined manner

Para meter	Portable water production		Food Production		Energy production from water		Com bined prod uction of water, food & energy
	(Pacini *et al.*, 2005)	(Wegelin M.,1996)	[17]	[18]	(Motwani, *et al.*, 2013)	(Gopina th. M.S. *et al.*, 2010)	
Cost	Approx- 5300/-	Constructional Cost US$60-80 per m^3/d Material cost- US$ 30-40 per m^3/d	Per acre costing 5395	Variable cost - $68.56(for dryland) and $132.67(irrigated area). Fixed cost- $24.39(for dryland) and $52.39(for irrigated area)	Initial cost = 25000/-	Cost of per KW Pico Hydro power Plant = Rs.30,000	Total Cost of the design = 19000-20000/-
Efficiency	Iron and manganese Removal efficiencies 85 % and 95 %.	High turbidity – 85-90% And For moderate turbidity 80-85%	75-80%	70-75%	60-80%	50-90%	Model efficiency =95% Water efficiency =80%-90%

Flowchart:



GMDH shell model.

Reliability and Uncertainty testing

The reliability and the uncertainty test are done on the design specifications of the model. This reliability is done with the help of Beers Law and uncertainty is done by Theil's Uncertainty coefficient (U). This Beer's law test helps to show the reliability of the

Name of the subject	Year of publication			Citations
	2012	2013	2014	
Energy Reuse	3931	4908	5958	The most cited articles (45 citation) [19]
Water reuse	4762	5698	6653	The most cited articles (247 citation) [20]
Micro Hydro Power plant	495	628	761	The most cited articles (76 citation) [21]
Vertical Irrigation System	5	2	4	The most cited articles (51 citation)[22]
Horizontal Roughing Filter	14	16	22	The most cited articles (9 citation)[23]

model and based on uncertainty coefficient we can also calculate the uncertainty of the model.

MATERIALS AND METHODS

Methods Used

The present study will require optimizing an objective function. The optimization was performed by two algorithms viz: DE & GSO.

Differential Evaluation Method

The technique differential evaluation has been applied to solve numerous problems in various fields such as mechanical engineering, pattern recognition and communications. It is a population based stochastic search global optimization technique. The three crucial parameter involved in DE is NP (number of population), F (scaling factor) and CR (Crossover rate) that significantly influence the optimization technique. Differential Evaluation technique used in power plant control (Cai *et al.,* 2008), automatic generation control for interconnected power systems with non-linearity (Mohanty *et al.,* 2014) and self-potential data generation (Wang *et al*., 2012) and neural network purposeI (Ilonen *et al.,* 2003).

The DE method can be applied in the real –valued problem over the continuous space (Mallipeddi and Suganthan 2010). It is similar to Genetic algorithm and it chooses the random population over the equal problem space and creates next generation donors [29].

$$\forall i \in n: D_i = X_a + F(X_b\text{-}X_c). \quad (1)$$

Where i, a, b, c are distinct

X_b and X_c are randomly chosen and X_a is chosen either randomly or the best population.

Ti,j is created as a trial vector by choosing between the donor vector and the previous generation for each element (j) according to the crossover rate CR[0– 1].

$$\forall i,j : if\ (random < CRkj = Jrand) then\ Ti,j = Di,j\ otherwise\ Ti,j = Xi,j \quad (2)$$

Where, J_{rand} is randomly chosen for each iteration purpose through i and ensures that no Ti is exactly the same as the corresponding Xi. Then the trial vector's fitness is evaluated. For each member of the new generation, X′ i, we choose the better performing of the previous generation, Xi, or the trial vector, Ti.

As this algorithm is a member of evolutionary group so it has all the merits of these algorithms: strong ability of global searching, versatility to problem features. Although this algorithm distinguishes itself from other algorithms by showing some unique features like strong capability to locate global optimum to high probability, better efficiency than other evolutionary algorithm, easier to tune fewer intrinsic control parameters and it is far more relaxing. Due to these advantageous side this algorithm are chosen. However, there are some disadvantages like this algorithm performs poorly for epistatic and noisy problems (Qing and Lee 2010).

Glowworm Swarm Optimization method

GSO is a nature inspired optimization technique that simulates the lighting worms' behavior. This algorithm is suitable for concurrent search of several solutions and also the equal objective function values.

In the GSO technique agents are randomly distributed in workspace. The agents in the glowworm algorithm carry a luminescence quantity known as luciferin. Agents are thought of as glowworm emits light whose intensity is proportional to the associated luciferin and also have a variable decision range r_i^d which is bounded by circular sensor range r_s.

The GSO technique that 1st initialize the parameters then update the luciferin value of the glowworm i

$$L_i(t) = (1-\rho) \times L_i(t-1) + \gamma J(X_i(t)) \quad (3)$$

Glowworm search the similar condition using the equation

$$N_i(t) = \{j: \left||Xj(t) - Xi(t)|\right| < r_d^i, Li(t) < Lj(t) \quad (4)$$

Then calculate the probability of distribution (Pij)

$$P_{ij} = \frac{Lj(t) - Li(t)}{\exists_{k \in Ni(t)} Lk(t) - Li(t)} \quad (5)$$

and updating the movement by using the equation of Xi

$$X_i(t+1) = Xi(t) + S \times [\frac{Xj(t) - Xi(t)}{||Xj(t) - Xi(t)||} \quad (6)$$

The method of GSO is totally memory less and gradient free for that reason it does not require the knowledge of any global information. The GSO technique is highly decentralized and caters in nature.

This GSO technique applied in several fields like multimodal functions where simultaneous capture of multiple local optima (Krishnanand and Ghose 2009), clustering approach, scheduling of single machine etc.

This GSO has a multimodal search capability to locate optimal centroids. In addition with this it has flexible and robust in nature (Aljarah and Ludwig 2013). These are the reason for selecting the algorithm. There are some disadvantages like searching speed and accuracy are less (Aljarah and Ludwig 2013).

Development of the ANN model

Artificial Neural Network is the computational model which is based on neural network structure and function. This neural network is always changeable in manner because it depends on input and output flow (Bourquin *et al*., 1998). The main advantage of this ANN model is that it learns from the observed data model (Stader and Macintosh 2000).

Here the model is predicted by comparing these design variables with the help of ANN model design software named as GMDH shell. For designing this model we have to take the input of length, breadth, height, various kinds of losses and precipitation and evapotranspiration and the output of this model are efficiency-cost ratio.

The main aim of this model generation is that from this predicted model equation in future the model can design. The prediction of the equation can be done by the help of using the observation data set.

Theils Uncertainty Coefficient and Beers Law

The U statistic developed by scientist Theils in the year of 1966 (Nellis *et al*., 1981). for the measurement of the accuracy of the model that emphasizes the large error and also it gives the correlation between the forecast variable data and the estimated value based on the explanatory variables. Theli's U accurately forecasts the model reliability. It is simple to work. Scientist Makridakis (Makridakis *et al.,* 1962). simplified the Theils formula which is shown below:

$$U = \sqrt{\frac{\sum_{t=1}^{n-1}\left(\frac{F_{t+1} - Y_{t+1}}{Y_t}\right)^2}{\sum_{t=1}^{n-1}\left(\frac{Y_{t+1} - Y_t}{Y_t}\right)^2}} \ldots \qquad (7)$$

Where, U= Theils U coefficient, F= forecasting, Y = Observation

By the help of Beers law (Murphy and Riley 2003) we calculate the reliability of the model. It measures the % of reliability (R^2) which is also known as coefficient of determination. This coefficient of determination is calculated on the basis rainfall-power graph. This graph shows the value of R^2.The beers law formula is

$$I = I_0 \times 10^{-(\alpha \times l \times c)} \qquad (8)$$

$$\alpha = \frac{A}{l \times c} \qquad (9)$$

Where, I= Intensity of the light passing through

3.2) Details Methodology**:**

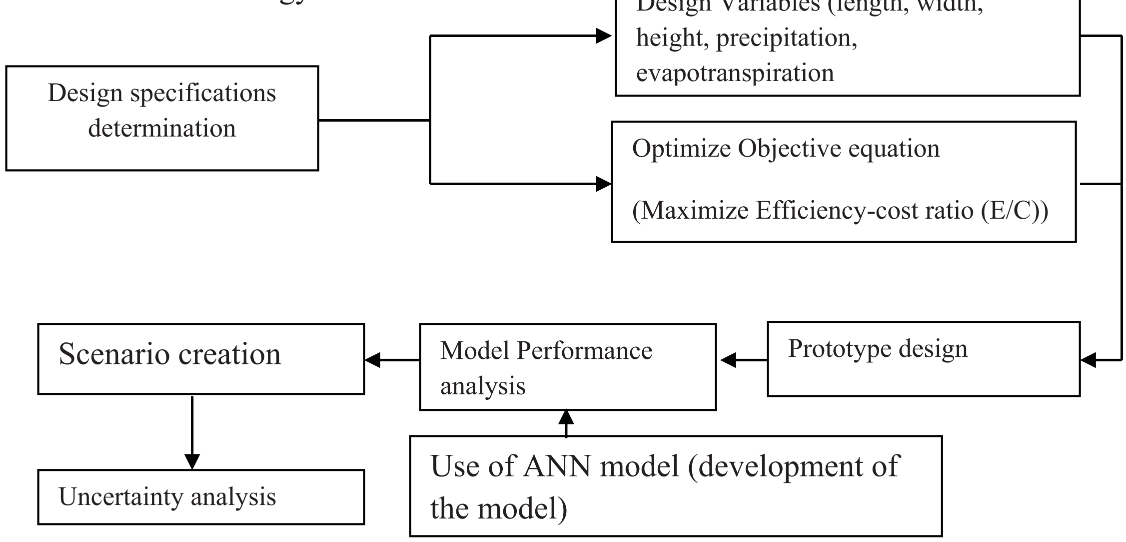


Table 4.1: Constraints applied to the design variables:

Variable / value	Length(l) (m)	Width(b) (m)	Height(h) (m)	Total Height (m)	Losses	(P) (m/month)	(Et) (m/month)
Min	0.61	0.61	0.61	0.61	0	0.007	0.004
Max	1.22	1.22	1.22	4.57	1	0.22	0.04

spectrometer, I_0= Amount of light intensity incident on sample, l= distance travel by light , c= concentration of absorber and α= absorption coefficient.

Details Methodology**: CHART**

The comparison of main two optimization technique GSO and DE gives the optimal design specification. These three dataset are taken on the basis of maximum efficiency-cost ratio.

Design Variables

The main considerable design variables for designing objective equation is length (l), width (b), head (h) of the tanks. These lengths, width and the height of the reservoir are proportional to the efficiency-cost ratio. All the variables are directly influence the efficiency but the cost also increases. But in comparison with efficiency increment of cost is low so if the volume increases the amount of storage water is high and its increases the efficiency. The several losses like dynamo loss (ΔV_d), water quantity loss in soil for crop production (ΔV_s), evapotranspiration loss (ΔV_e), pump loss (ΔV_{pump}) are consider as a variables for the objective equation because for maximum efficiency-cost ratio the losses should be minimum. Under the climatic variables precipitation (P) and evapotranspiration (Et) are mostly needed design variables. If the precipitation increases then it will increases the model efficiency but evapotranspiration is directly inversely so it may decreases the model efficiency. With the help of Optimization tools we are able to find the maximum efficiency by minimizing the installation cost of this model.

Necessary Assumptions and Constraints

For this objective equation we take a few assumptions for maximizing the efficiency of model and under minimum cost. The maximization of efficiency-cost ratio of the system is the main aim. The upper and lower bound have to take in a feasible range for the length, width and height of the tank. We consider the losses as constraints which is range in between the 0-1. Literature reveals the last 10 years value of the rainfall and evapotranspiration from which we get the minimum and maximum value of this.

The above table shows the feasible range of the design variables. The optimization techniques are used this range for generate the design specifications where the efficiency-cost ratio is maximum.

Objective Equation

The main objective equation is the model efficiency and cost ratio:

$$\frac{Efficiency(E)}{Cost(C)} = \frac{(l \times b \times h) - \Delta\mathrm{Vd} - \Delta\mathrm{Vs} - \Delta\mathrm{V}_{eva} - \Delta\mathrm{V}_{pump})/V_1}{\{P + (v + V) \times r\} + \{(l + L) \times r_p\} + (S \times r_s + g \times r_g + st \times r_{st})} \tag{10}$$

Using this above equation maximum efficiency-cost ratio has to decide by the help of optimization procedure. The objective equations are developed depending on the variables. The procedures of that optimization are briefly discussed in step wise manner.

V_1 = Reservoir volume (input water volume)
= l*b*h where l, b and h is reservoir length, breadth and height

V_2 and V_3 is volume of water in 2nd and 3rd tank. V_4 is output water

Efficiency Maximization Equation

Power generation equation:

$$P = \rho \times g \times Q \times H \tag{11}$$

Where, ρ= water density, Q=discharge of water, H= height /depth of the tank

$$Q = \{(p - Et) \times l \times b\} + \Delta V_{pump} \tag{12}$$

Putting the equation 1 in equation 2

$$P = \rho \times g \times H \times \{(p - Et) \times l \times b\} + \Delta V_{pump} \tag{13}$$

Where, p=precipitation, ET=evapotranspiration, l & b= length and breadth and ΔV_{pump} = Water through pump which are used to uplift the water from lower to upper reservoir

$$V_2 = V_1 - \Delta V_D \quad (14)$$

Where ΔV_D= volume of water passes through dynamo

V_3=V_2-ΔV_s

Where ΔVs=volume of water stored in the 2nd tank

$$V_3 = (l \times b \times h) - \Delta Vd - \Delta Vs \quad (15)$$

$$V_4 = V_3 - \Delta V_{eva} - \Delta V_{pump}$$

$$V_4 = (l \times b \times h) - \Delta Vd - \Delta Vs - \Delta V_{eva} - \Delta V_{pump} \quad (16)$$

Energy,

$$E = V_4/V_1$$

$$Efficiency = (V_4 = (l \times b \times h) - \Delta Vd - \Delta Vs - \Delta V_{eva} - \Delta V_{pump})/V_1 \quad (17)$$

Cost Minimization

Initial costing:-

Labour cost: P

Types of material: r

Total volume of material:

$$-(l * b * h) + (m * n * o) = v + V \quad (18)$$

Where, v= volume of water in the 1st tank.

V= volume of another tank

L=length of 1st penstock

L= length of 2nd penstock

Cost©:

$$- \quad C = \{(v + V) \times r\} + \{(l + L) \times r_p\} \quad (19)$$

HRF costing:

$$S \times r_s + g \times r_g + st \times r_{st}$$

Where, S= sand r_s= cost of sand

g=gravel and r_g = cost of the gravel

st= stone and r_{st}= cost of stone

Total cost:

$$C = \{P + (v + V) \times r\} + \{(l + L) \times r_p\} + (S \times r_s + g \times r_g + st \times r_{st}) \quad (20)$$

Penstock diameter calculation

Discharge

$$Q = A \times V \quad (21)$$

Where, A= area of the pipe & V= velocity of water through pipe

From Bernoulli's Equation,

$$\frac{V^2}{2 \times g} + \frac{P}{\rho \times g} + Z = H \quad (22)$$

Where, V= Velocity of water, P= pressure of water, ρ =density of fluid at all point of fluid, g= acceleration due to gravity, Z= elevation of the point above a reference plane and H= total head.

Here,

$$P = F \times A$$

Where, F= force of the fluid and A= area of the tank

Again area of the pipe

$$A = \pi \times r^2 \quad (24)$$

r= radius of the pipe

Programming Technique

The nature based optimization algorithm: DE and GSO was used as a programming technique for the present optimization problem

Design of the Prototype

This model is a multipurpose water reuse and power production system. In this model there are mainly 3 parts are present. 1st part is used for micro hydro power generation, 2nd part is for crop productivity and 3rd one is used for drinking water purpose. In that 1st part rain water is captured in the reservoir. The stored water of reservoir passes through penstock and its rotate the dynamo blade and produce electricity of the amount of approximately 1 kw/day. This amount of energy is stored in the battery and used for the household.

After this procedure the water comes to the 2nd reservoir and reused for crop cultivation. The chick pea, mustard seed all are suitable for the cultivation purpose in that chamber. After used in that chamber water spillway through the soil. In the next reservoir the spillway water is stored. This stored water is used for drinking purpose after purification through Horizontal roughing filter as well as excess water will be send to the 1st reservoir through motor. If this prototype developed it can able to generate electricity in low cost for a household. By selling the crop and the drinking water we can reimburse the installation cost.

Model Development for Performance Analysis of the Design System

This three optimized design specifications are developed with the help of optimization technique. This design specification is tested with the help of ANN model. ANN method predicts the model on the basis of optimized value and it compares the predicted model with analytical model. This comparison gives the correlation value of the predicted model and shows the percentage of error in that model.

This ANN model is done in the GMDH software. Here the input variables length, breadth and height. The output and the target values are efficiency-cost ratio. The datasets are import in that software and then it is forecast the data for prediction purpose. The equations are generated with the help of the sub-models. ANN model is prediction based models which is useful to develop accurate model and to generate the error of the model by comparing predicted and accurate data.

Scenario Creation

Design Scenario

Scenario analysis is the process of analyzing possible future events by considering alternative possible outcomes. It is the main method of the projection of a model. It can be used in an exploratory manner for the purpose of scientific assessment for understanding the functioning of an investigated system (Foley *et al*., 2005).

Climatic scenario

If the climatic parameter which is consider as a beneficiary part of the model will change then the output of the prototype will also change. So for getting the suitable design specifications few climatic scenarios have to create for analyze the design with respect to climate and by comparing the result of the scenario optimum design are selected. The basic climatic scenario for this above mentioned model is depending on the Rainfall. The max monthly rainfall is 0.23 m and the lowest value of the rainfall is 0.007m. This scenario is created by increasing and decreasing the maximum and minimum precipitation in 0.02 intervals respectively.

Model various demand scenarios

Climatic Scenario

Model Reliability & Uncertainty

Reliability and Uncertainty testing is very much essential for the model on which we can analyze the model reliability.

In the Uncertainty testing part Theils U coefficient calculation followed several steps:

$$H(X) = P_x^{(X)} \times \log P_x^{(X)} \quad (25)$$

Design 2:

Name of the scenario	Precipitation (m/mon)	Length (m)	Width (m)	Head (m)	ΔV_d	ΔV_s	ΔV_{eva}	ΔV_{pump}	Evapotranspiration (m/mon)
S1(011111111)	0.27	1.18	1.21	1.226	0.197	0.192	0.44	0.038	0.066
S2(111111111)	0.25	1.18	1.21	1.226	0.197	0.192	0.44	0.038	0.066
S3(211111111)	0.23	1.18	1.21	1.226	0.197	0.192	0.44	0.038	0.066
S4(311111111)	0.007	1.18	1.21	1.226	0.197	0.192	0.44	0.038	0.066
S5(411111111)	0.005	1.18	1.21	1.226	0.197	0.192	0.44	0.038	0.066
S62(511111111)	0.003	1.18	1.21	1.226	0.197	0.192	0.44	0.038	0.066

Design 1:

Name of the scenario	Precipitation (m/mon)	Length (m)	Width (m)	Head (m)	ΔV_d	ΔV_s	ΔV_{eva}	ΔV_{pump}	Evapotrans-piration (m/mon)
S7(000000000)	0.27	1.05	1.134	1.2	0.337	0.22	0.44	0.56	0.069
S8(100000000)	0.25	1.05	1.134	1.2	0.337	0.22	0.44	0.56	0.069
S9(200000000)	0.23	1.05	1.134	1.2	0.337	0.22	0.44	0.56	0.069
S10(300000000)	0.007	1.05	1.134	1.2	0.337	0.22	0.44	0.56	0.069
S11(400000000)	0.005	1.05	1.134	1.2	0.337	0.22	0.44	0.56	0.069
S12(500000000)	0.003	1.05	1.134	1.2	0.337	0.22	0.44	0.56	0.069

$$H(X!Y) = P_{x,y}^{(X!Y)} \times \log P_{x,y}^{(X!Y)} \quad (26)$$

$$U = \frac{H(X) - H(X!Y)}{H(X)} \quad (27)$$

This Theils coefficient Result shows that predicted model uncertainty.

RESULTS AND DISCUSSION

Optimization Result

By using the optimization techniques like DE and GSO three design specifications are determined. After few iteration process in both optimization technique comparisons are done and the three optimum design specifications are selected.

The Optimization Result (3D graphical view)

In the graph if the data's are set in the 1st quadrant then the graph is said to be accurate. In this graph the model optimal design values are laying in the 1st quadrant of the graph and that satisfies the models accuracy.

In the table 6.4 the normalized values of cost and efficiency are taken with respect to the volume of reservoir. The normalized values are done by divided the each value by average value of the column. These values are taken on the basis of optimization result. Then taking these normalized values of cost and efficiency two graphs are drawn with respect to the volume. These two graphs cut at the same point. This

Design 3:

Name of the scenario	Precipitation (m/mon)	Length (m)	Breadth (m)	Head (m)	ΔV_d	ΔV_s	ΔV_{eva}	ΔV_{pump}	Evapotran-spiration (m/mon)
S13(022222222)	0.27	1.168	1.13	1.204	0.372	0.219	0.438	0.262	0.058
S14(122222222)	0.25	1.168	1.13	1.204	0.372	0.219	0.438	0.262	0.058
S15(222222222)	0.23	1.168	1.13	1.204	0.372	0.219	0.438	0.262	0.058
S16(322222222)	0.007	1.168	1.13	1.204	0.372	0.219	0.438	0.262	0.058
S17(422222222)	0.005	1.168	1.13	1.204	0.372	0.219	0.438	0.262	0.058
S18(522222222)	0.003	1.168	1.13	1.204	0.372	0.219	0.438	0.262	0.058

Table 4.1: Design 1 dimensions and specifications

	Mini Mum	Maxi Mum	Value (m)	Weightage	Discharge (m^3/day)	Power (w/day)	Energy efficiency	Crop Production (gm/mon)	Water efficiency (%)	Amount of water use and reuse	Cost
Length	0.61	1.22	1.058025	1.021922	0.536897	958.3 W Per day	0.9798	708.6 gm per month=340 ml	82.6%	Water use= 1443 litre Reuse water=1183l = 39 litre per day	Installation Cost in Rs 19899
breadth	0.61	1.22	1.134135	1.368133							
height	0.61	1.22	1.202697	1.522644							
Gross Height	0.61	4.57	4.53	1.16							
ΔVd	0	1	0.337231	1							
ΔVs	0	1	0.219254	1.349579							
ΔVeva	0	1	0.438471	1.375635							
ΔV_{pump}	0	1	0.562553	1.428328							
Preci	0.007	0.23	0.197633	0.762258							
evapotra	0.004	0.4	0.069014	1.036356							

Table 4.2: Design 2 dimensions and specifications

	Mini Mum	Maxi Mum	Value (m)	Weightage	Discharge (m^3/day)	Power (w/day)	Energy efficiency	Crop Production (gm/mon)	Water efficiency (%)	Amount of water use and reuse	Cost
Length	0.61	1.22	1.188025	1.121922	0.576897	993.3 W per day=1kw/day (approximately)	0.988	872 gm per month=418 ml	85.67	Water use= 1768 litre Reused water=1514 l= 50 litre per day	Installation Cost in Rs 19560
breadth	0.61	1.22	1.214135	1.368133							
height	0.61	1.22	1.22697	1.522644							
Gross Height	0.61	4.57	4.57	1.16							
ΔVd	0	1	0.197231	1.54							
ΔVs	0	1	0.19254	1.349579							
ΔVeva	0	1	0.038471	1.375635							
ΔV_{pump}	0	1	0.662553	1.428328							
Preci	0.007	0.23	0.227633	0.762258							
evapotra	0.004	0.4	0.069014	1.036356							

Table 4.3: Design 3 dimensions and specifications

	Mini Mum	Maxi Mum	Value (m)	Weightage	Discharge (m^3/day)	Power (w/day)	Energy efficiency	Crop Production (gm/mon)	Water efficiency (%)	Amount of water use and reuse	Cost
Length	0.61	1.22	1.168025	1.21922	0.456897	896w per day	0.9798	786gm per month=377 ml	75.57	Water use= 1572 litre Reuse water=1282 l= 38 litre per day	Installation Cost in Rs 19989
breadth	0.61	1.22	1.134135	1.268133							
height	0.61	1.22	1.202697	1.22644							
Gross Height	0.61	4.57	4.5	1.1							
ΔVd	0	1	0.37231	1.87							
ΔVs	0	1	0.219254	1.49579							
ΔVeva	0	1	0.438471	1.275635							
ΔV_{pump}	0	1	0.262553	1.228328							
Preci	0.007	0.23	0.127633	1.762258							
evapotra	0.004	0.4	0.058014	1.036356							

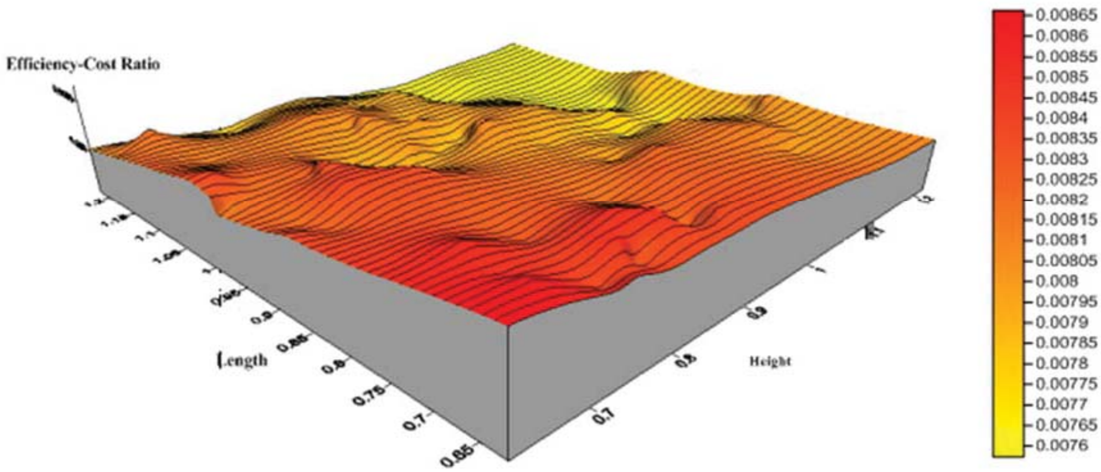


Fig 4.1: The efficiency-cost ratio variation with respect to length and height of the reservoir4

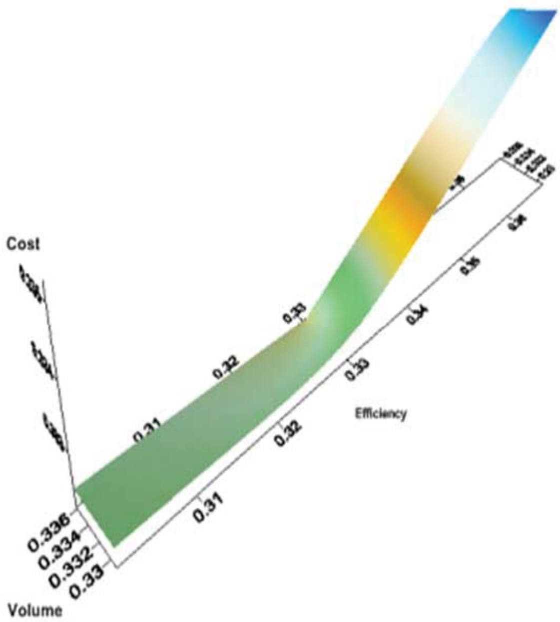


Fig 4.2: graphical representation of Optimum design

Table 4.4: Normalized value (Unit less) of the design

Design	Volume	Cost	Efficiency
Design 1	0.30	0.33	0.33
Design 3	0.33	0.34	0.33
Design 2	0.37	0.33	0.34

meeting point is the optimum point and this design is optimum design.

$$Normalized\ Value = \frac{Individual\ value}{Average\ of\ the\ each\ column}$$

Pipe diameter Calculation

Q= 0.019m^3/day, g= 9.81, ρ= 999.9kg/m^3, F=force of water in the tank= 1359 litre water force =.3331N, A= 1.49m^2.

By putting this value in the equation 16, we get Diameter =7inch

So the pipe diameter=7inch.

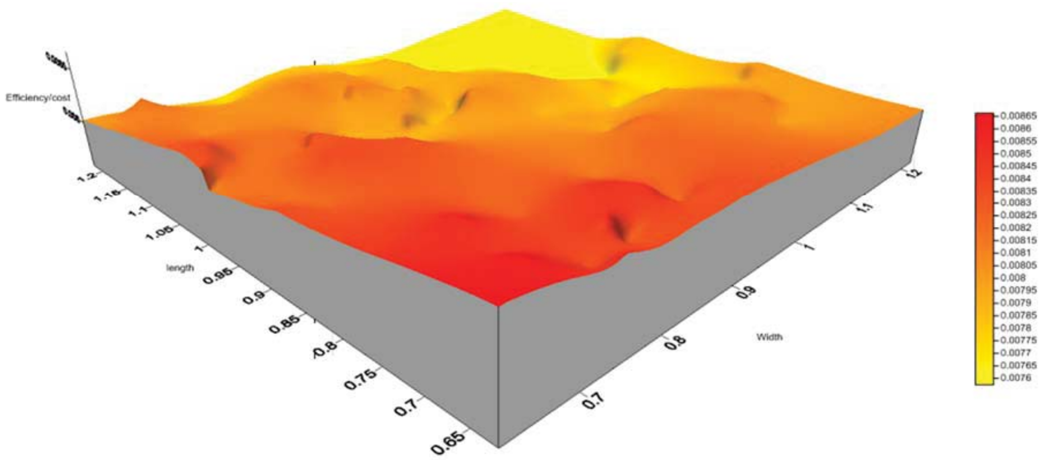


Fig 4.6: Variations of efficiency-cost ratio with length and height

Performance Analysis of the Model

The model is tested through ANN and it's developing the predicted model for the output of the prototype. By generating the ANN predicted model we can able to develop the prototype equation based on which this can be develop in future.

This surface curve determines the variations of efficiency-cost ratio with respect to length and width.

The accuracy table shows the model accuracy results. The correlation of the predicted model is 0.9995 and the coefficient of determination is 0.9991. From this it is easily said that the above model is accurate enough. The erroneous value is also minimize for this model.

Demand Scenario Result of the Model

Model various demand scenario analysis result: TABLE

Reliability and Uncertainty Testing of the Model

Theil's Uncertainty Coefficient (U) =0.005562

This uncertainty shows that model uncertainty is 0.005562.

Reliability Analysis

In this system design purpose the design specifications are optimized based on several parameters. The parameters are the basic variables for maximum power production and water reuse of this model. The optimization process is used and three design specifications are developed. The DE and GSO are the two program techniques which are used for optimization process. Using these design specifications the model was designed. For the model design purpose the ANN tool is used. Among these three specifications after comparing the various

Model various demand scenario analysis result

E/c / Scenario	Design 1	Design 2	Design 3
S1	-	0.078	-
S2	-	0.07815	-
S3	-	0.07816	-
S4	-	0.0762	-
S5	-	0.07621	-
S6	-	0.07622	-
S7	0.07	-	-
S8	0.0714	-	-
S9	0.0715	-	-
S10	0.0689	-	-
S11	0.0688	-	-
S12	0.0686	-	-
S13	-	-	0.0733
S14	-	-	0.0733
S15	-	-	0.0733
S16	-	-	0.0722
S17	-	-	0.0722
S18	-	-	0.0722

Table 4.8: Accuracy Result

Post processed Result	Model fit	Prediction
Number of observation	69	30
Normalized mean absolute error	0.107%	0.208%
Normalized root mean square error	0.236%	0.235
Standard deviation of residuals	0.236%	0.234%
Coefficient of determination(R^2)	0.999	0.9991
Correlation	0.9996	0.9995

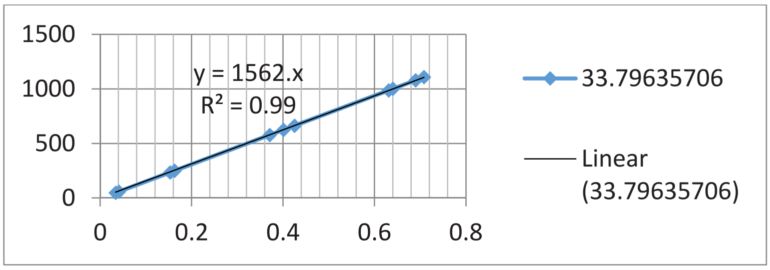


Fig 4.6: Reliability Curve of the Model

Table 4.9: Climatic scenario vs Design table

Scenario / Design	Climatic Scenario	Comment
Design 1	Efficiency-cost ratio=0.07-0.073	Efficiency-cost ratio is low
Design 2	Efficiency-cost ratio=0.077-0.0772	Efficiency-cost ratio is High
Design 3	Efficiency-cost ratio=0.0742-0.0743	Efficiency-cost ratio is Medium

design scenarios for all the specifications optimal design is generated. The best design specifications are generated through comparing scenario criteria which is given below.

According to the Table it is clearly seen that Design 2 is best suitable result for satisfying this overall demand scenario among the other design. This design satisfies the basic demand criteria and also gives the higher efficiency-cost ratio rather than other two designs. This model solves a major problem of the society.

The prototype provides a new apparatus to conserve both water and energy. The system can also create a source of income from the crop produced and fresh drinking water generated from the system. Also at the time of low demand this model can supply electricity to the grid and thus can earn a substantial income from selling electricity.

Furumai (2008) reviewed the advantages of rainwater using in the agricultural field and in the domestic purpose. This rainwater harvesting, the collection and storage of rainfall runoff is widely used in arid and semiarid regions. The reuse of water is also discussed in this paper. Rain water increases the crop yields. Also the energy consumption for rain water supply to household purpose is very much less than traditional water supply. The advantageous side of rain water harvesting in the agricultural and domestic purpose is low cost, high energy efficiency, less adaptation and simple operation.

Pacey and Cullis (1986) analyzed the opportunity in rain water harvesting system. In proper management precipitation can reduce the water and food crisis of the regions. Rainwater constitutes a potential source of drinking water as well as agriculture purpose also. In order to support many developing countries RWH technology is a effective system which is basically based on local skills, materials and equipments. This harvested rainwater can be effectively used for rainfed agriculture and drinking water purpose in a single household. This rainwater might be polluted by bacteria and microbes sometimes so it should be filtered through roughing filters and then water can be used for drinking purpose.

Rahman *et al.,* (2014) describe an innovative and decentralized system which can be used to collect and treat rainwater for power generation purposes. These systems can fulfill a single household demand or a small community. The total unit cost is low and this system is efficient also.

Thus the new system can help any individual to ensure water, energy as well as food security. Thereby a scientific implication of this model is that this model can serve the power generation purpose along with crop cultivation and drinking water production. The design may solve the electricity problem of the rural area as well as the water and food scarcities are resisting by this design. It also helps to earn money by selling the water, crop and the excess electricity at the time of low demand .This design based on rain water harvesting.Therefore need of the ground or surface water. Finally the model efficiency is high and cost is low than single system.

CONCLUSION

Literature reveals that the amount of energy and water is reducing day by day as per demand. Due to this high increase rate of demand-consumption ratio the future generation is going to face the scarcity of energy and water after some years later. These scarcities may hamper the daily life of population and disrupt the development of the civilization. Consider this current scenario the model is developed which will produce a power using rain water as well as crop cultivation and drinking purpose are solved with this same water. This is a mini structure which can generate almost 1 kWp/day power at low cost. This much of power is sufficient for the single household purposes. The main advantage of this model is use and reuses the water for several times which reduce the installation cost up to 50% comparing with separate model and efficiency is also high. The maintenance cost of the model is relatively high and thus this model is depends on precipitation so there will be some variation in power production with climatic change. There is some time lag occurs at the time of uplifting water. As a future work the maintenance cost of this model should be reduced by using the optimization procedure, the number of iteration should be increased in the process for getting much suitable design specifications and finally the costing of this material have to minimize. The time lag for the pump to uplift the water will have to calculate in the future work. From this calculation the time lag can be minimized for the system by adding some other features or by improving the piping system of the prototype. By utilizing this model, the future demands of electricity and water can be minimized to some extent.

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