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Research Paper

Sustainable Energy and Environmental Management in a Solar Powered Adaptive Fuzzy Control Model for Ground Water Conservation in Rural India

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Abstract - *In the present paper, a novel scheme of water level management of a storage tank, adaptive to varying water consumption by an end user, has been designed. This system proposes the intelligent control of water supply from storage tank fed from reservoir and supplemented through ground water in rural areas. The control action has been simulated and validated, for its satisfactory performance, by fuzzy control logic. The proposed control system optimizes water consumption, leading to improvement in the ground-water life cycle and increasing the life of pumps and bore wells. Moreover, it reduces wastage of water, maintains the water table which is depleting day by day due to ecological unbalance leading to water crisis, more demand and its consumption. It avoids damaging conditions for pump arises due to muddy ground water, without any inconvenience to the user. In the proposed system, keeping in view the poor grid power availability in rural areas, a solar-power PWM inverter supply has been used with highly efficient submersible pump with more than 50% saving in electricity. The reservoir tank regularly supplies water daily in varying time schedule to the storage tank fulfill the demand of water to end users. In the absence of the water in reservoir, or when the supply from the reservoir is insufficient to meet the demand, the submersible pump, operating on PV stored energy, acts as a supplementary source of water supply. It pumps water to the storage tank in accordance to the demand/consumption of water. This has been achieved with a fuzzy controller, which senses the varying level of water in the storage tank and the end user requirement, and fills up the storage tank from the reservoir tank and/or the submersible pump accordingly.*

Keywords : Water table, Submersible Pump, PV power, Sensors Total Harmonic Distortion (THD

Introduction

The demand for water has increased over the years and this has led to water scarcity in many parts of the world. The importance of groundwater for the existence of mankind cannot be overemphasized. Groundwater is one of the major sources of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Groundwater crisis is not the result of natural factors; it has been caused by human actions. During the past two decades, the ground water level in several parts of the country has been decreasing rapidly due to an increase in extraction for agriculture purposes. Even for supply of water in dry low water level urban area water supply is made through rural area only Some of the negative effects of ground-water depletion include increased pumping costs, deterioration of water quality, reduction of water in streams and lakes, land subsidence etc. It has been found that if the pump, used for pumping ground water, is continuously used for a long time then muddy water starts rising and thus mud and other sediments choke the pump and it gets damaged. This is because the rate of percolation of water inside the ground varies from place to place and the replenishment of the ground water requires some time [1]. The ground water chemistry is generally not known. Thus, to tackle this problem an optimal system needs to be designed which can maintain the rate of extraction of ground water at an optimal level as per the user's requirement. Apart from this, the other common problems faced are the wastage of water due to overflow of tanks, storage of large amount of water in tanks for long time, and damage to pumps due to water table going down below the pipe-length in summer season. These secondary problems have also been investigated and solved through this project [2]. Here, a system with optimal control has been proposed, which uses PV energy [3] for pumping the ground water and supplying it to the storage tanks. The most important objective served by the proposed system is that it maintains the extraction rate of ground water at the optimal level sustaining the water resources in the power saving of around 50 %. The efficiency of the PV system is also high as PWM techniques and intelligent control strategy have been used to generate grid quality power with THD < 5%. Further the system offer cost effectiveness as it operate the smaller size (low rating) of self priming submersible pump motor as compared to commonly used high rated large size(high rating) jet pump for pumping ground water to the storage tank.

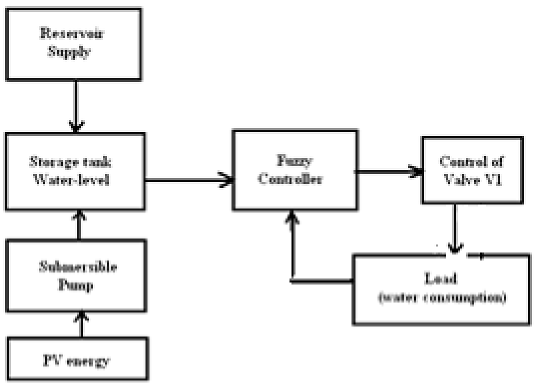


Figure1: Pumping and storing water in storage tank

System Control Operation

The system control module consists of solar powered submersible pump controller, water supply control unit with sensors, storage tank and reservoir tank as shown in Figure 2. There are three sensors positioned at different locations. One sensor is present in the bore well to sense the ground water level. The second sensor, with multi sensing elements at different vertical positions, is put in the tank being used for storing the pumped water. The third sensor is responsible for sending the feedback about load i.e. water consumption pattern (rate). The reservoir acts as a primary source for the storage tank. It continuously fills the storage tank in time schedule as per the user's requirement. The valve V2 controls and limit the supply of water from the reservoir into the storage tank. If the supply from reservoir tank [5], is insufficient to meet the user-requirement, then the submersible pump (which is acting as a supplementary system) starts operating. The valve V1 is then controlled to pump water in the storage tank. The control of valve V1, i.e. the time for which it is operated, is in accordance to the level of water in the tank and the user-requirement. Here, both the reservoir and the submersible pump are in operation. If the environment as well as meeting the demand of water in suburban areas [4]. This in turn allows the ground water to percolate at natural rate and also increases the life time of the bore well and the pump. The adaptability feature incorporated in this helps to track the rate of water consumption and accordingly adjusts the supply, thus avoiding water stagnation and preventing wastage due to overflow. These constraints have been simulated, applied and tested for its outcome in the proposed prototype (Figure1) which includes PV panel, Battery, a fuzzy controlled water supply tank, through a solar powered submersible pump, resulting in reservoir is not supplying water at all, then only the submersible pump will operate. Again, the time of operation of the pump depends on the water-level in the storage tank and the water consumption. Thus our system constantly tracks the consumption and intelligently adapts itself to give an optimum performance. The technical specifications of proposed system has been reflected in Table (1).

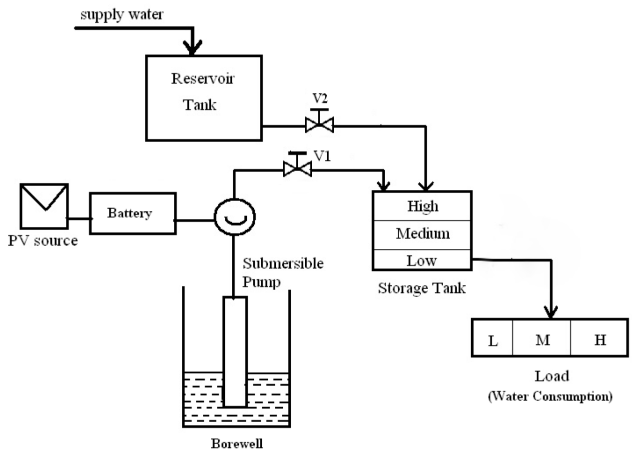


Figure 2: Schematic of the Control System of Proposed Model

Table (1): Technical Specification

S.N	Parameters	Specification(s)
1	Solar (PV) panel	4x75Wp,12V
2	Battery	2x80Ah ,12V SMF
3	Storage Tank	1000 liter-3000liter
4	Controller	Fuzzy, Micro-controller/FPGA implementable
5	Sensors	Smart, RF technology
6	Control valves	Solenoid ,230VAC
7	Inverter	230V, 50 Hz , PWM ,THD <5%
8	Pump	1Hp, Submersible , Head -15feet

Fuzzy Control Algorithm

Fuzzy logic control has been used as an intelligent tool to manage the extraction of ground water in case of varying water requirement and fluctuating water-supply from the submersible pump and the reservoir. The control designs are setting the constraints, assigning the linguistic variables and setting the rules for the controller. The water-consumption and the level(quantity) of water present in the storage tank are varying inputs. The control of valve V1 i.e. the operation-time of the submersible pump, is the output variable of the system. Since these input parameters represented by membership function are to be fuzzified, equation (1), the max-min method of fuzzification, [6,7] is used to set the fuzzy rules of the controller.

$$\mu = (\alpha 1 \wedge \mu 1) \vee (\alpha 2 \wedge \mu 2) \qquad \text{Eq. (1)}$$

Where, μi = action dictated by the ith rule
$\mu(i)$= truth value of rule
$\alpha 1$ & $\alpha 2$ are the input variables

Similarly, since the valve control unit cannot respond directly to the fuzzy controls, [8] the fuzzy control sets generated by the fuzzy algorithm have to be converted to crisp values by using the method of defuzzification. Subsequently, the approximate centre of gravity (COG) method, supposed to be the most accurate method to get a crisp value is used for the defuzzification, as shown in equation (2).

$$COG = \frac{\sum \mu i \, \mu(i)}{\sum \mu i} \qquad \text{Eq. (2)}$$

Where, μi = action dictated by the ith rule
$\mu(i)$= truth value of rule

A) Input Variable : Load and ST level 1000 liter

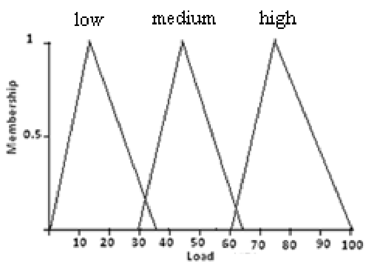
Load : Low : trim f (0 15 35)
Medium : trim f (30 45 65)
High : trim f (60 75 100)

ST level : Low : trimf (0 15 35)
Medium : trimf (30 45 65)
High : trimf (60 75 100)

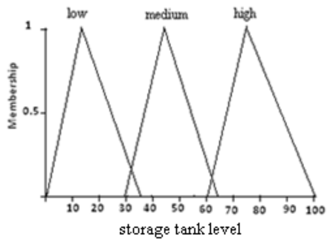
B) Output variable : Operational time 1 hour(max)

V1- control : Min : trapmf (0 0 20 60)
Max : trapmf (30 65 100 100)

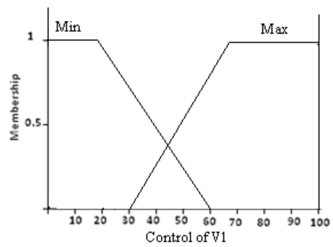
The graphical display of membership functions for input and output variable are shown in Figure 3.



(a)



(b)



(c)

Figure 3 : Membership function for (a) load (water consumption) (b) storage tank level (c) output i.e. control of valve V1

Fuzzy Rule

Knowledge based decisions, according to the input conditions of storage tank level as one parameter and load (water consumption) another parameter , have been

If Load is L And ST level is L : Then V1 is min
If Load is L And ST level is M : Then V1 is min
If Load is L And ST level is H : Then V1 is min
If Load is M And ST level is L : Then V1 is max
If Load is M And ST level is M : Then V1 is min
If Load is M And ST level is H : Then V1 is min
If Load is H And ST level is L : Then V1 is max
If Load is H And ST level is M : Then V1 is max
If Load is H And ST level is H : Then V1 is min

formulated as a fuzzy rule data base as shown in Table 2. The output data (i.e. control of the valve V1) regulates the operating period of the valve, evaluated as a crisp value using centre of gravity (COG) method.

Table 2: Fuzzy Rule

ST level / Load	Low	Medium	High
Low	Min (1)	Min(2)	Min(3)
Medium	Max(4)	Min(5)	Min(6)
High	Max(7)	Max(8)	Min(9)

The rules explain the working principle of control action as follows :
The meanings of the labels designating the names of linguistic values are :
ST : Storage Tank ; V1 : Valve 1 control ; Min : Minimum ; Max : Maximum.; L ; Low ; M Medium ; H : High

Case Study

A case study of control action of system for a typical day at particular instant has been analysed. The sample data, acquired for given input conditions, has been computed for control output as operational time in % as follows:

Load (63) : Medium (0.1) & High (0.2)
ST level (32) : Low (0.15) & Medium (0.133)

Rules fired are 4, 5, 7 and 8

Strength of rule 4 : [0.1 ^ 0.15] = 0.1
Strength of rule 5 : [0.1 ^ 0.133] = 0.1
Strength of rule 7 : [0.2 ^ 0.15] = 0.15
Strength of rule 8 : [0.2 ^ 0.133] = 0.133

Centre of Gravity Method: The crisp value has been computed by substituting the data in eq.(2).

$$\frac{65 * 0.1 + 0.1 * 20 + 0.15 * 65 + 0.133 * 65}{0.1 + 0.1 + 0.15 + 0.133}$$

= 55.6 % Eq (3)

Simulation Result

The software implementation of the proposed system has been done using the fuzzy tools of MATLAB ver 7.1.

The computational data as reflected by Eq (3) has been validated with this tool.
The graphics of simulated input and output parameters and results have been shown in the Figures 4,5,6,7,8,9 and 10.

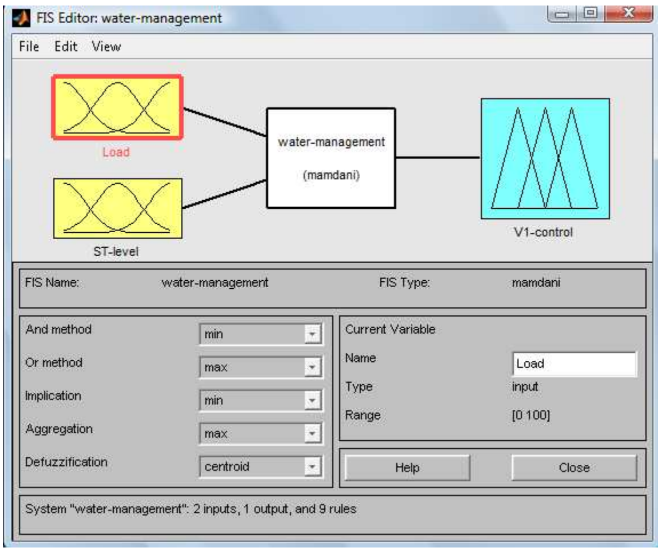


Figure 4 : The FIS editor

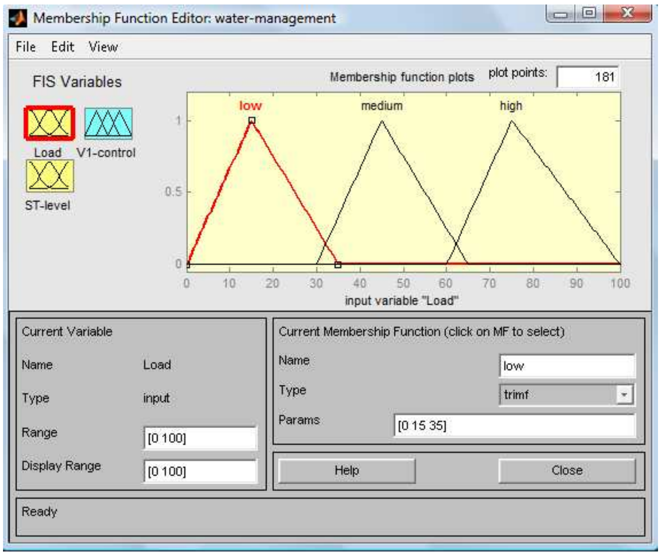


Figure 5: Membership function for Load

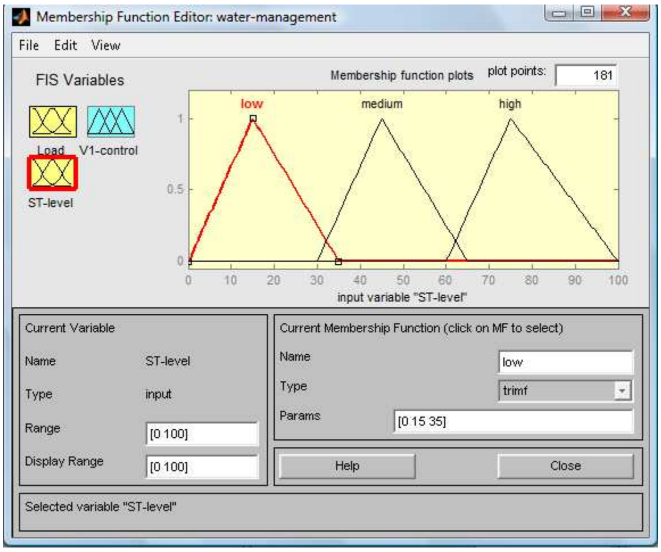


Figure 6: Membership function for storage tank level

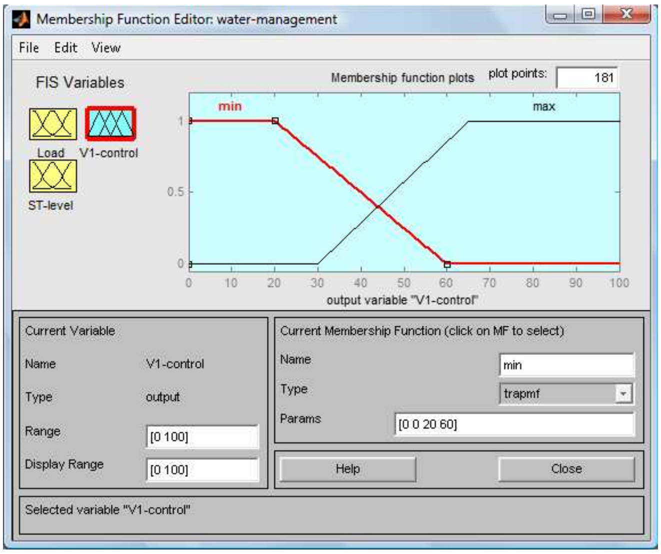


Figure 7: Membership function for control of the valve V1

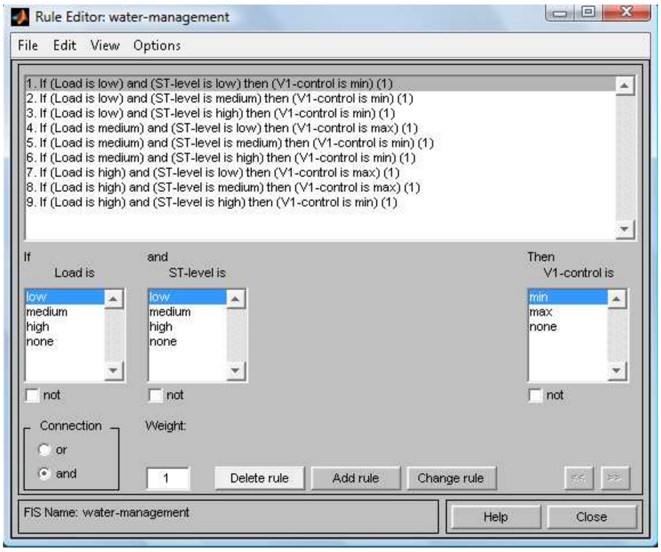


Figure 8: If - then rules for the proposed system

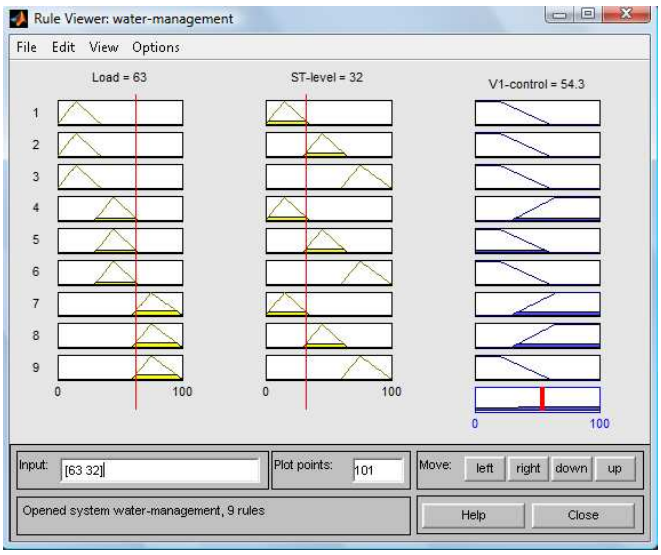


Figure 9: Rule Viewer

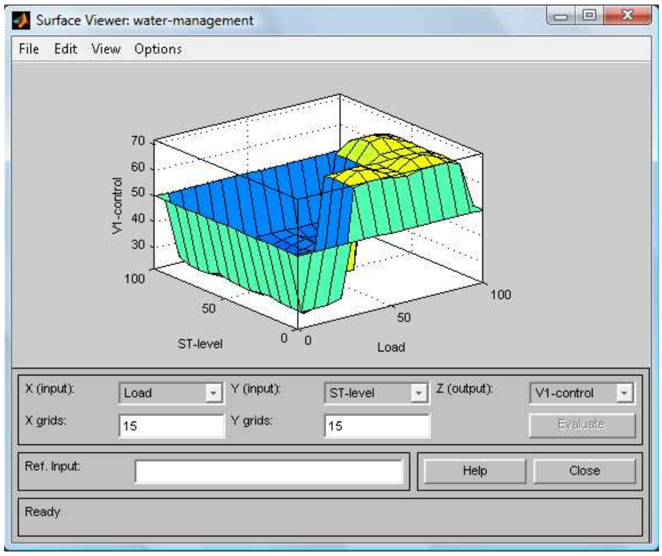


Figure 10: Surface viewer

Conclusion

The decreasing trend of water table is a great concern throughout world especially in a country like India where population is increasing day by day. A control system has been proposed for the management of water supply of reservoir tank to storage tank in order to meet the user's requirement and also control the optimal use of ground water to maintain the water table. As the rate of ground water extraction is more than its replenishment, the water table is decreasing day by day. Moreover, it is damaging the pump also. To overcome such problems, an intelligent control system has been proposed, which uses a solar powered submersible pump to draw ground water in a controlled manner. The pump is operated by standalone PV system. The storage tanks are regularly filled in daily during varying time schedule with water from the reservoir. But in circumstances when water in reservoir is either not available or it is insufficient to meet the demand for water at any instant, the submersible pump is used to fill water in the storage tank as per the user's requirement. In this way, we are conserving the ground water without any wastage of water, maintaining the water table, preventing damage to pumps and also saving grid electricity by using solar (PV) energy to operate the pump. In this project study a fuzzy based control model has been used and its control action has been validated successfully with MATLAB software tool. The proposed study has led to following outcomes:

a) Meeting the increasing demand of water and its conservation
b) Environmental protection with green solar electricity
c) Energy conservation through grid power saving with the use of solar electricity
d) Easy implementation of proposed fuzzy control strategy through microprocessor/microcontroller or FPGA embedded chip.

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