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A Novel Fuzzy Logic Solar (PV) - Grid/DG Powered Pump Controller for Efficient Water Management

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Abstract. Water-management is an interdisciplinary field concerned with the management and optimum utilization of water. The consumption of water is increasing due to rapid growth of population. Further due to ecological changes, the open reservoir systems water storage and its availability is shrinking every year. Thus underground source of water has become the major source of water pumped through submersible pump at domestic end. On the other end, excessive and continuous use of water through this pump may lead to depletion of water table. In order to avoid this, an optimal control system for water-management has been proposed in the present project work. This has been achieved by controlling the operational time of a solar water pump in an optimal way. An efficient fuzzy model has been proposed in simulation environment to develop such an adaptive control system and its implementation in a residential building has been studied.

Keywords: Water Management, Solar cell, Fuzzy controller etc.

1 Introduction

Around the globe water tables are falling, underground aquifers are being depleted and lakes are shrinking. Wasting water, cold or hot, causes huge energy and pollution problems. Enormous amounts of water are consumed every day, in toilets, showers, laundry and taps. Did you know that 97% of the world's water is salty or otherwise undrinkable? Another 2% is locked in ice caps and glaciers. That leaves just 1% for all of our needs - agricultural, residential, industrial, community and personal. The United Nations recommends that an individual person needs a minimum of 13 gallons (50L) of water every day.

The conservation of water is really a global issue that we should all be a part of. It is something that everyone can get behind no matter what your background is, where you’ve come from, or what your beliefs are. It’s a simple fact that conservation of water is incredibly important and there are human lives at stake. Water management is an interdisciplinary field concerned with the management of water resources. People in this field are concerned with ensuring that a supply of clean, potable water will be available to people who need it, while balancing the needs of industry and the environment. Other people in this field are more concerned with how humans use water resources. A large area of water management is concerned with the use of water in industries, agriculture and domestic areas. The proposed system is a step towards water conservation at the very grass root domestic level. The consumption of water is increasing day by day due to growth of population. The underground water is pumped through submersible pump and is used for drinking as well as irrigation purpose. People are facing water crisis everywhere due to ecological unbalance causing low rain leading to lowering of water table. In this present study, investigation has been carried out to explore the possibility of optimal uses of water pumped through submersible pump in a residential hostel building and thus preserving the water table of underground water. This is an energy efficient optimum usage of water to protect wastage due to bad practices.

A fuzzy based automatic controller has been developed as an extension work carried out earlier [1 2 3 4] for optimal operation of the submersible solar power water pump being used in residential hostel as a case study with the following objectives:

- Optimize the operating timing of submersible pump according to the demands and availability of water in the service tanks.
- Energy conservation by using solar energy as a primary power source to run pump, lighting etc.

The varying inputs to the fuzzy control system will be:

- Demands of water
- Water availability in the water tanks from other sources

By knowing the above two parameters we can determine the optimum time of running of the water pump. Since we are using a fuzzy based control system, the output, that is the time of running of the pump, will depend upon a set of rules developed by the experience of an expert. The efficiency of the system is linearly dependent on the accuracy of the inputs. The system model with controller has been shown in Fig.1.

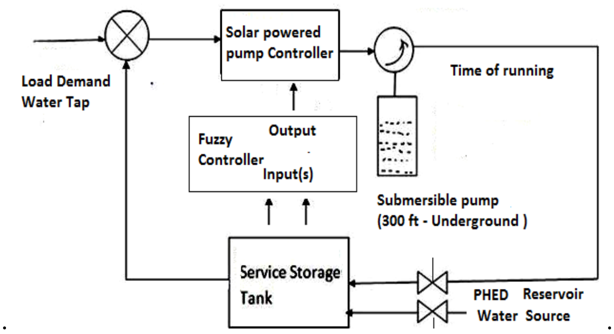

Fig. 1: System model of water management system

The system comprises of a fuzzy controller, service tank, submersible pump powered through a solar power red battery backed up inverter and controlling valves. The timing of pump operation is regulated through fuzzy controller which takes the inputs from service tank and supplements the availability of water as per user demand at an interval of every one hour throughout day and night.

1.1 Solar Power Converter

The block diagram of PV power supply and is shown in Fig 2.

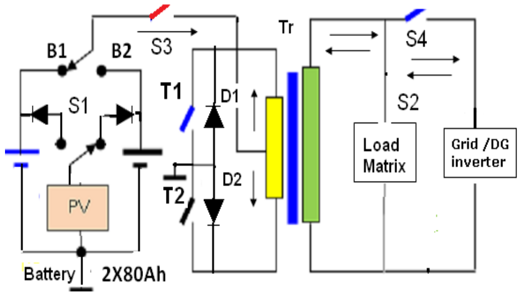

Fig.2: Proposed power circuit model of a grid/DG assisted solar (PV) power supply for pump motor

The solar power supply system makes use of the solar (PV) module to produce DC electricity and subsequently convert it into AC power that can be supplemented by a stand by grid inverter/diesel generator as and when needed. The dual battery system of PV unit controlled through DPDT switch S1 as shown in Fig.2 feed power to load from one of battery (i.e. B1/or B2) bank while other bank of battery (i.e. B2/or B1) store energy from PV source and thus could be able to deliver power for 24 hours in a day. The bi-directional inverter converts DC power from the 12V battery to SPWM AC power 220V +/- 20%, 50Hz for the load. The battery (B1/or B2) will supply power to load to its maximum discharge level 10.4V. The base drive pulses generated by controller using IC oscillator circuits CD 4047 switch on and off the transistor devices T1 and T2 alternatively for 10ms and thus produces 50Hz AC voltage waveform across load due to centre tap transformer (Tr) action. The base load pump is normally fed from primary PV inverter source whereas in case low PV power energy is drawn from grid/DG source.

2 FUZZY CONTROL SYSTEM MODEL

2.1 Fuzzy controller

The control strategy for operation of pump from integrated hybrid power has been shown in Fig 3. The system controller determines the starting or stopping of the pump as decided by controller. Determining the best condition of operation is the key to achieve optimum operation.

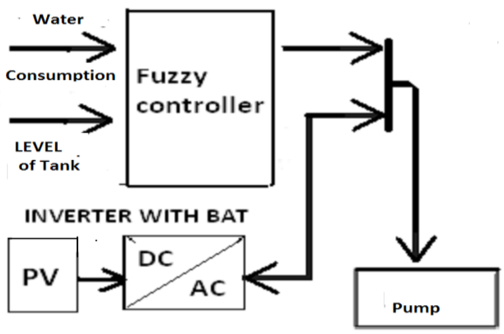

Fig. 3: A fuzzy control strategy model of pump controller

2.2 Fuzzy Control Algorithm

Fuzzy logic control has been used as a tool to manage the water level in tank. The procedure in making the control designs are setting the constraints, assigning the linguistic variables to inputs and output, setting the rules for the controller. Water demand and water level in tank are the areas that affect the studied as inputs where as the output variables of this controller are the turn-on time period of the pump. The objective of the designed controller is to control as per desired turn-on time period of the pump, these had to be changed by fuzzification through membership function (μ). The max-min method i.e. Equation (1) of has been used to set the rules of the controller

$$\mu = (\alpha_1 \wedge \mu_1) \vee (\alpha_2 \wedge \mu_2) \quad (1)$$

Where, α_1 and α_2 are variables corresponding to individual membership functions μ_1 and μ_2.

Since the output variable cannot respond directly to the fuzzy controls, the fuzzy control sets generated by the fuzzy algorithm have to be changed back by using the method of defuzzification. Subsequently, the approximate centre of gravity (COG) method as shown in equation (2) is used for the defuzzification.

$$COG = \frac{\sum_{i=1}^{n} \mu_i \mu(i)}{\sum_{i=1}^{n} \mu(i)} \quad (2)$$

The Fuzzy control system [6] has been formulated with two inputs and delivers single output as follows:

- Input 1 - Water level in the service storage tank (proportional to PHED water supply)
- Input 2 – Load Demand in the hostel (directly proportional to the number of residents and the usage of water by them)
- Output – Time of running of the water pump

Data acquisition for Inputs parameter:

- **Input 1** - PHED water supply obtained water reservoir source (water level in the service storage tank) - (0 to 100%) (Fig 4)
- **Input 2** – Load Demand in the hostel (directly proportional to the number of user (hostel resident) and the usage of water by them) - (0 – 100%) (Fig 4)

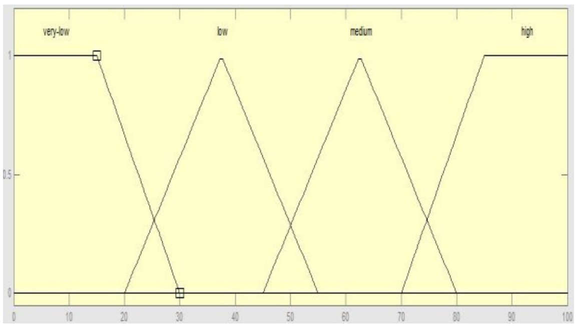

Fig. 4: Input membership functions for Input 1 and input 2

Both the inputs have the same membership functions. Trapezoidal and Triangular functions are used as they are the most conventional and easy to implement. There are four membership functions:

- Very-low

- Low
- Medium
- High

The fuzzy system will determine the output by evaluating the defined rules of the membership functions of the inputs.

Data delivered for the output

Controlled paramour (Fig 5) has been taken as:

Time of running of the water pump – (0 to 100%)

There are 4 membership functions used for the output. Two of them are trapezoidal and two of them are triangular. The membership functions are:

- Very-less
- Less
- Medium
- High

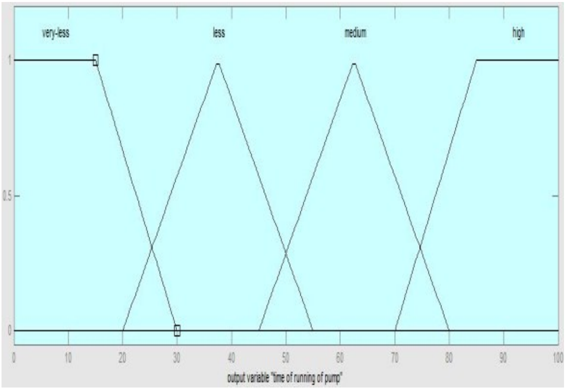

Fig. 5: Output membership functions

Rule Matrix:

The decision of expert (Table 1) is formulated as follows:

Table1: Fuzzy Rules for output controlled parameter

I - 1 I - 2	VL Very Low	L Low	M Medium	H High
VL	L	M	H	H
L	LE	LE	M	H
M	VL	LE	LE	M
H	VL	VL	LE	M

Where,
I-1 is the "load (water tap)" and I-2 is the "service tank level". The various levels are designated as follows VL: very Low, L, Low, LE Less, M: Medium, H: High.

3 Results and Observation

Results has been validated for a case study using fuzzy logic tool of MATLAB software (Ver-7):

Input 1 (Load) – 25%
Input 2 (Level of Water) – 75%

Expected desired Output -25%
(Operational time of pump)

Fuzzy Rule viewers and Surface viewers

The output is shown in (Fig 6 and Fig 7) for the case study under consideration:

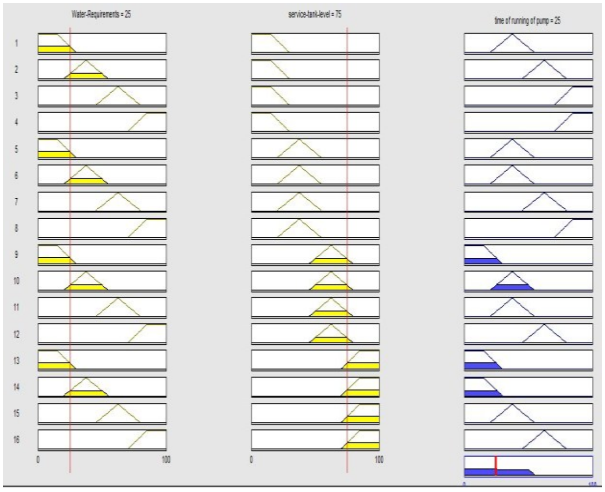

Fig. 6: Rule Viewer

Actual output (Time of running of the pump): 25%

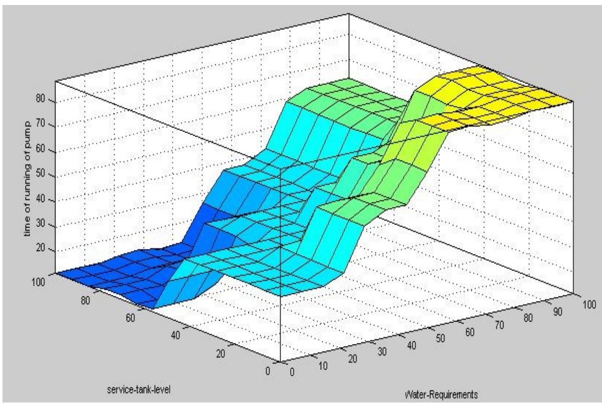

Fig. 7: Surface Viewer

4 Conclusions and Future scope of work

A fuzzy controller system has been developed to manage optimally the water level in the service tank. The simulated result has resulted in the balance between supply and demand of water in a residential hostel building. The future implantation can be extended for integration of multiple numbers of residential buildings . in a colony of town and village.

The project has successfully been implemented in the residential hostel building and following benefits has been achieved

- Reduction in wastage of water.
- Saving of energy by optimal running of the pump.
- Rules based on expert's experience have increased reliability.
- Cost effective system

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Appendix:

The codes used to develop the fuzzy control system in Matlab is given under:

```
[System]
Name='water management2'
Type='mamdani'
Version=2.0
NumInputs=2
NumOutputs=1
NumRules=16
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'
 [Input1]
Name='Water-Requirements'
Range=[0 100]
NumMFs=4
MF1='very-low':'trapmf',[-22.9 -10.8 15 30]
MF2='low':'trimf',[20 37.5 55]
MF3='medium':'trimf',[45 62.5 80]
MF4='high':'trapmf',[70 85 101 103]

[Input2]
Name='service-tank-level'
Range=[0 100]
NumMFs=4
MF1='very-low':'trapmf',[-22.9 -10.8 15 30]
MF2='low':'trimf',[20 37.5 55]
MF3='medium':'trimf',[45 62.5 80]
```

```
MF4='high':'trapmf',[70 85 101 103]

[Output1]
Name='time of running of pump'
Range=[0 100]
NumMFs=4
MF1='very-less':'trapmf',[-22.9 -10.8 15 30]
MF2='less':'trimf',[20 37.5 55]
MF3='medium':'trimf',[45 62.5 80]
MF4='high':'trapmf',[70 85 101 103]

[Rules]
1 1, 2 (1) : 1
2 1, 3 (1) : 1
3 1, 4 (1) : 1
4 1, 4 (1) : 1
1 2, 2 (1) : 1
2 2, 2 (1) : 1
3 2, 3 (1) : 1
4 2, 4 (1) : 1
1 3, 1 (1) : 1
2 3, 2 (1) : 1
3 3, 2 (1) : 1
4 3, 3 (1) : 1
1 4, 1 (1) : 1
2 4, 1 (1) : 1
3 4, 2 (1) : 1
4 4, 3 (1) : 1
```